IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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MEETINGS AND PAPERS

PITTSBURGH SECTION

R. F. Chaffin, Chairman — J. F. Kelly, Secretary

Saturday, April 16th, 1927

Blue Room, Wm. Penn Hotel.

Dinner 6:30 P. M. — Technical Session 8:00 P. M.

Subject:

"Frequency Converter Speed Sets," by Mr. G. P. Wilson, Electrical Engineer, Westinghouse Electric & Manufacturing Company.

PHILADELPHIA SECTION

Saturday, April 2nd, 1927

"General Ideas and Discussions," by Members Philadelphia District Section.

All meetings, unless otherwise noted, will be held at the Engineers' Club, 1317 Spruce Street, and will start promptly at 7:30 P. M. Dinner at 6:00 P. M.

CHICAGO SECTION

Tuesday, April 12th, 1927

"European Electrical Practices as Observed," by Mr. A. M. McCutcheon, Reliance Electric & Engineering Co., Cleveland, Ohio.

BIRMINGHAM SECTION

Saturday, March 26th, 1927

"An Automatic Starter for a Synchronous Motor," by Mr. J. H. Hall, Assistant Engineer, Electric Controller & Mfg. Co., Cleveland, Ohio.

Saturday, April 30th, 1927

"Inductive Time Limit Control," by Mr. N. L. Mortensen, Ass't. Ch. Engineer, Cutler Hammer Mfg. Company.

Chairmen and Secretaries

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EDITORIALS

The following editorials are answers to the editorial which appeared in the February issue of our Iron and Steel Engineer on the subject of "We are Standardized On."

The editorials appearing herewith reflect the opinions of two operating engineers and are not to be construed as the policy of the Association of Iron and Steel Electrical Engineers nor of the Iron and Steel Engineer.

This editorial space is open to both the manufacturers and the buyers who wish to express their ideas and opinions relative to the application of electricity, fuel, mechanics and safety to the Iron and Steel Industry. *Editor.*

PROGRESS vs. STANDARDIZATION

The recent editorial written by a Sales Manager under the caption, "We Are Standardized On," looks at the question solely from the viewpoint of the selling of a new or possibly improved product or perhaps the introduction of an old product into a new territory. He gives slight consideration to the merits of the other side of the question.

I think I am safe in saying that in few, if any, other industries have the operating Electrical Engineers been as willing to assist in the trying out and actual development of apparatus as have we of the Steel industry. It is also equally true that in those Plants where quantity of product and costs are carefully studied the best results are obtained in the smooth running standardized departments where not only has the "spare part" argument certain definite bearing on results, but also the familiarity of the actual repair and maintenance men with the so-called "standardized" apparatus is a very vital factor in the elimination of delays and continuity of operation which make for high production and low costs.

There are therefore many instances where standardization has been the means of progress in certain lines of work. It is undoubtedly true that carried to the extreme, standardization combined with the exclusion of all interest in the advances of the art would sooner or later result in retrogression, but I repeat again such conditions are not characteristic of the electrical development in the Steel Industry. We are, however, very vitally interested in the question of a reasonable period of protection of existing apparatus on the part of the manufacturers of electrical and mechanical equipment so that we will be able to purchase spare parts on fair cost basis rather than on a basis of expensive special spares for obsolete equipment.

I think that all those of us who are actually alive to the problems of our Purchasing Departments realize that extreme standardization is at times a bar to best prices and we accordingly are more than willing to give place to new equipment whenever the price situation seems clearly to overshadow the advantages we are enjoying from our standardized operation.

The history of the gradual electrification of the Steel Industry has at all times been characterized by the spirit of investigation and trial of new and better equipment so that where Mr. Sales Manager finds himself unable to sell through a barrier of standardization he must be charitable enough to realize that perhaps the operating man has certain grounds for his stand.

It would be entirely unfair to close this reply without paying a tribute of recognition and respect to our friends, the Sales Engineers, whom we are glad to meet and deal with and from whom we are always able and willing to learn something of value to our operation.

—"SO AND SO HAS STANDARDIZED ON"—

Once upon a time, an inquisitive steel mill electrical man wanted to investigate "Safety Switches," so he purchased a sample of each make of switch that was on the market, and mounted them side by side on a rack in his test room—and, after looking them over, decided that none of them met his requirements. That is the mill man's story—but an army of safety switch salesmen toured the steel mills and, on the basis of these experimental purchases, each claimed that "So and So" had standardized on his particular switch.

For another exhibit, we can consider the renewable fuse salesman—"most rugged fuse on the market with a case that is never destroyed, standardized on by "So and So and So and So and So and So." When several of these claims were examined, it was discovered that the Purchasing Department usually placed the business with the low bidder, and the particular steel plant might be using a dozen different makes of this product, and all doing the work satisfactorily.

And then there have been several cases of commutation trouble that were "corrected" by the salesman of each make of brush that was permitted to be tried out—until the manufacturer discovered that the sparking was due to the design of the machine.

Then, for the greatest example of them all, we have "The Ford Motor Co. uses them by the carload"—and we can believe it or not, depending on how our receptive imagination is working on that particular day.

Now we can pass on to another phase of the subject entitled, "This Equipment is now one of our Standard Products—Has been under development many years—All the Bugs are out of it—Put one in and forget it"—and you do. One month later, the

(Continued on page 171)

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Steam Turbine Development*

By ERNEST PRAGST†

THE purpose of this paper is to present a brief review of the more important accomplishments which have occurred in steam turbine development in the United States during the past twenty-five years and to describe in greater detail some of the more modern turbines.

I will confine myself solely to the consideration of one type of machine, or, more specifically, to those of the impulse type, with which I am most familiar, as manufactured by the General Electric Company, leaving the treatment of other types to those who have been more intimately associated with their development.

Progress has been several-fold. It has had as primary ends reduction in the cost of producing power, improvement in reliability and simplification, provided simplification could be obtained without sacrificing economy or reliability. Evidences of the means by which these ends have been sought, and to no small extent realized, are not lacking. Witness the improvements in turbine efficiency, extension of the operating heat range, the introduction of stage bleeding of steam for feed-water heating and the reheating of steam after partial expansion, the increases in the sizes of units and their speeds, changes in manufacturing methods and designs facilitating standardization and quantity production, etc.

Here a pertinent question suggests itself: Granting that these advances have been made is a simple quantitative measure of them possible? Comparisons of output, physical sizes, costs and thermal economies of machines afford, perhaps, a reasonable means of determining progress quantitatively. A simpler and more impressive, if less accurate, measure, I believe, is through a comparison of station sizes and operating economies. Choosing such an approach to the subject of turbine advancement, one must be cautious, remembering that the improvement shown in a comparison of this kind includes the contributions of the plant designer, boiler, stoker, condenser and other apparatus manufacturers as well as those of the turbine manufacturer. But it is the station as a whole which is of most interest to operators, and it is largely from the view-point of the station operator that most of the members of the A. I. & S. E. E. will measure progress. Twenty-five years ago, or in 1901, the largest turbine under construction (not then manufactured) was of 5000 kw. capacity. A 50,000 kw. station to contain ten such units represented the limit of optimistic expectation at the time. Now, stations designed for ultimate capacities as great as 1,000,000 kw. are seriously considered.

In 1903 a station employing 5000 kw. turbine-generators (the most economical units then in service) and the best boilers, condensers and other station equipment then available was capable of reaching an overall thermal efficiency of 10.15 per cent, which, with coal of 13,500 B.t.u. per pound, is equivalent to the production of one net kw-hr. from 2.5 pounds of coal. Let us contrast this with the record of a modern station of 1925—for example, the Philo Station of the Ohio Power Company on the Muskingum River. This station, designed for 600 pounds pressure and to include the most modern means of securing high economy, has been able to deliver a kw-hr. to the outgoing lines from 13,715 B.t.u. in coal. This corresponds to 24.8 per cent thermal efficiency, or, correcting for coal of 13,500 B.t.u., 1.02 pounds of coal per net kw-hr. For a month this station has averaged 14,300 B.t.u. in coal per net kw-hr. produced, equivalent to an overall station thermal efficiency of 23.9 per cent and 1.06 pounds of 13,500 B.t.u coal per kw-hr. The coal actually burned at the Philo Station when these records were established, had a heat content of less than 13,500 B.t.u. per pound. Table I shows the progress made in overall station thermal economy, between 1902 and 1926, of steam-electric generating stations operating in commercial service.

TABLE I*

Year	Size of Units in Kilowatts	Thermal Efficiency in Per cent	Fuel Consumption in lbs. per kw-hr. of 13,500 B.t.u. coal
1903	5000	10.15	2.50
1908	14000	15.0	1.69
1913	20000	18.0	1.41
1918	35000	21.6	1.17
1925	40000	23.9	1.06

Reference to this table shows from 1903 to 1925 a gradual reduction in fuel consumption from 2.5 to 1.06 pounds per kw-hr., or a decrease of 58 per cent. Of course, this is a measure of station progress as a whole, considered in terms of thermal economy alone. With this advance, turbine development has kept pace and contributed appreciably to the ultimate results. In a previous paper** before this association, Mr. D. B. Rushmore and I presented curves showing the growth in sizes of turbine-generators, the increases in operating steam pressure and temperature and the improvements made in their thermal efficiencies and steam consumptions, all plotted against time and covering the period from 1903 to 1922. Now, let us review hurriedly the physical characteristics of the more important machines built during the last quarter-century and, so, trace the evolution of the modern turbine-generator, with the hope that it will aid us in reaching better an understanding and appreciation of the modern machines.

The first large turbine-generator built by our company was furnished the Commonwealth Edison Company of Chicago about 1902 and installed in their Fiske Street Station. It was of the vertical type, 5000 kw. capacity, operated at 500 r.p.m. and had two stages. The next step came in 1906 and consisted of

*Presented before Pittsburgh Section, February 19, 1927.

†Engineer, Industrial Engineering Department, General Electric Company, Schenectady, New York.

*See: "A Review and Forecast of the Electrical Industry," by E. W. Rice, Jr., General Electric Review, August, 1918, page 528; "Operating Results at Philo," Power, May 12, 1925, page 720; "Philo Station Sets Record," by Mr. L. Sindeband and Mr. P. Sporn, Electrical World, August 22, 1925, page 355.

**"Station Development," by D. B. Rushmore and E. Pragst, Proceedings of A. I. & S. E. E. for 1922, page 473.

an 8000 kw. vertical machine (see Fig. 1) having five stages and operating at 750 r.p.m The machine illustrated was equipped with a surface condenser base. During 1908 a 14,000 kw. unit, having the same number of stages and operating speed, was produced, and this was followed in 1911 by a 20,000 kw. machine essentially similar to the 14,000 kw. type. With its manufacture ended the development of the vertical type turbine. During this period of nine years, turbine designers were able to increase the speeds of the larger units from 500 to 750 r.p.m., their capacities from 5000 to 20,000 kw. and thermal efficiencies nearly 50 per cent.*

From this time on, horizontal types supersede the vertical types. The change was dictated largely through the development of high speed generators, improved materials, the increase in steam pressures and temperatures, and through a more accurate knowledge of the performance of turbines gained from the experience obtained with those previously

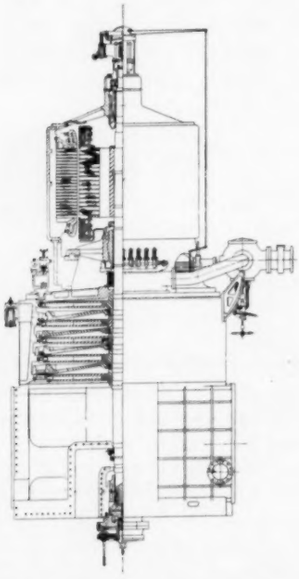

FIG. 1—Cross Section of an 8000 KW, 750 RPM, 5 Stage Vertical Steam Turbine.

constructed. All of these pointed towards and made possible a more compact construction, higher speeds, a greater number of stages, smaller diameters, and, so, a longer machine which could best be made with a shaft designed to operate in a horizontal plane.

The first large horizontal machine (see Fig. 2) was rated 20,000 kw., 1200 r.p.m. and had nine stages. Several were constructed and placed in service during 1913-14 in Chicago, Detroit and Cleveland. The next step came in 1914 in the form of 20,000 kw. machines (see Fig. 3) to operate at 1800 r.p.m. and with water rates superior to those of the 1200 r.p.m. machines of the same capacity. This type consists of high and low pressure turbines mounted integral, employing a common shaft and forming a single unit. The high pressure end, or turbine, contains ten stages and is designed for uni-directional flow. The low pressure end is arranged for double flow, the steam entering at the center and flowing in opposite directions, and, in each direction, traversing two stages before reaching the exhaust opening. This construction is now usually referred to as tandem-compound. Following almost immediately on the completion of these machines (two of them were built) came a 35,000 kw., 1200 r.p.m. design, the largest single shaft machine built up to that time.

During 1916-17, because of the conditions incident to the war, there came demands from the power companies operating in the industrial centers for large turbine-generators to have high efficiency and

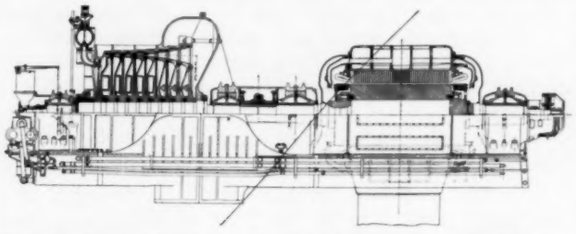

FIG. 2—Cross Section of a 20,000 KW, 1,200 RPM, 9 Stage Horizontal Steam Turbine.

still be economical in their requirements of material and floor space. These conditions were met by a 30,000 kw, 1800 r.p.m., 17 stage design. (See Figs. 4 and 5.)

Perhaps this has been the most popular large capacity turbine ever built. Eighty-seven of them are now in operation. Of these, six are in the Windsor Station of the American Gas and Electric Company, five in the Delaware Station and four in the Chester Station of the Philadelphia Electric Company and eight are operating in Cleveland. These are just some of the larger and, therefore, more striking installations that come to mind.

During the same time—1917—the Detroit Edison Company, because of the rapid growth of their load, expressed a need for still larger machines. This requirement was met by the development of a 45,000 kw., 1200 r.p.m., 21 stage machine. The design does not differ materially from that of the 30,000 kw., 1800 r.p.m. machines. These units were the largest single casing turbines built up to the time they were

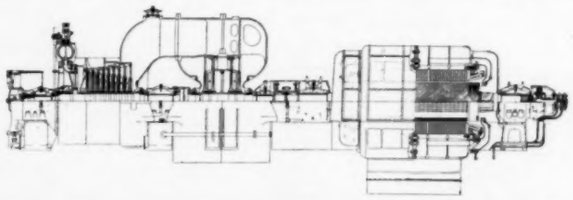

FIG. 3—Cross Section of a 20,000 KW, 1,800 RPM, 12 Stage Horizontal Steam Turbine of the Tandem-Compound Type.

placed in service. Each was direct connected to a single 45,000 kw. generator through a flexible coupling.

Parenthetically, permit me here to call your attention to the fact that we have been confining ourselves solely to a review of types of turbines designed for use in public utility and industrial generating stations. Simultaneously with the work we have been considering, the steam turbine was being introduced into marine service. We must forego the temptation of digressing here to follow the history of its adaptation to ship propulsion, confining our-

*See: "Station Development," by Rushmore and Pragst, Proceedings A. I. & S. E. E., 1922, page 485.

selves closely to the turbine as prime-mover in steam-electric generating stations. Otherwise we might wander far afield and not be able to keep the time required for our presentation and discussion within reasonable limits.

After the development of the 45,000 kw., 1200 r.p.m. turbine, for several years progress was largely a matter of improvement in the existing types—essential, but, as such progress usually is, not spectacular. Then came a query from a group of engineers about to build a new high economy station, seeking to learn "the largest single cylinder 1800 r p.m. unit suitable for a steam pressure of 550 to 600 pounds, steam temperature 725 deg. F. with reheating of the steam after partial expansion." 40,000 kw. was decided upon as a conservative maximum capacity for such a turbine. Two machines of this size, and meeting the steam and speed conditions outlined, were built and shipped in 1924. These formed the initial installation at the Philo Generating Station of the American Gas and Electric Company.

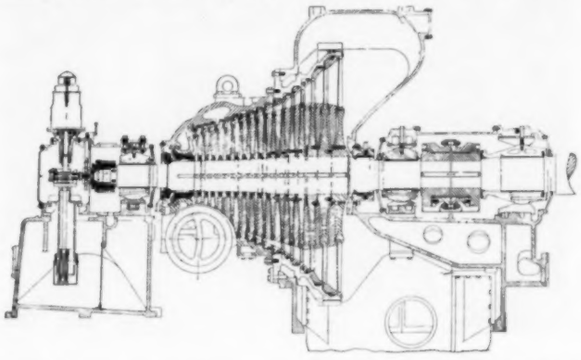

FIG. 4—Cross Section of a 30,000 KW, 1,800 RPM, 17 Stage Steam Turbine.

This turbine was built with a single casing containing 19 stages (see Fig. 6). A diaphragm was placed between the seventh and eighth stage wheels. Under normal conditions of load and operation, steam is exhausted from the casing at approximately 110 pounds pressure after passing the seventh stage wheel. The steam is then reheated to 725 deg. F. when it is re-entered into the turbine casing at the eighth stage. It then passes through the eighth stage nozzles and wheel and subsequent nozzles and wheels until it reaches the nineteenth stage wheel from whence it passes finally into the exhaust hood and condenser. Two of these units are installed in the Philo Station and two in the Twin Branch Station of the American Gas and Electric Company. Because of their high thermal economy, they have contributed substantially to the highly commendable performance of the Philo Station referred to earlier in this paper.

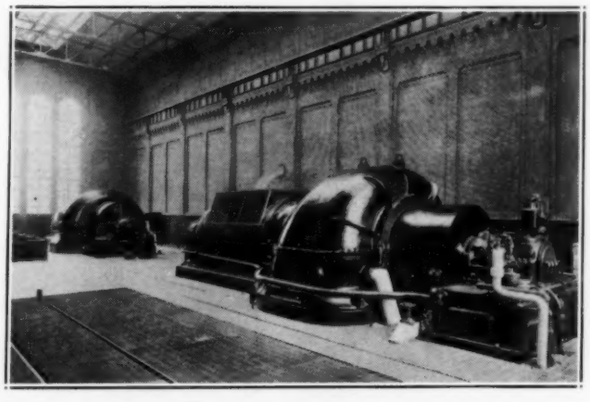

FIG. 5—A 30,000 KW, 1,800 RPM, 17 Stage Turbine Generator in the Station of the Illinois Power and Light Company at Des Moines, Iowa. A 20,000 KW unit is shown in the background.

During the past three years—1924-6, besides the omnipresent efforts to improve, along conventional lines, the mechanical construction and efficiency of turbines, four important classes of developmental work have been distinctly discernible although mutually dependent. I submit: first, the work done to increase the capacities of turbines of a given speed, centering largely around 1800 and 3600 r.p.m., 60 cycle machines; second, the construction of extremely large units employing separate high and low pressure turbines driving the same generator or separate generators, but in each case designed to operate together as a unit; third, the development of a system of parts standardization for 3600 r.p.m. turbines to facilitate the design and manufacture of turbine-generators within reasonable limits of costs but with good efficiencies to meet the exacting and multifarious demands of industrial customers seeking high overall plant economies; and, fourth, experimentation to determine means of further improving the thermal cycle and thus obtain an improved generating station performance. The order employed here does not necessarily represent the relative importance of the several lines of development prosecuted during the past few years. These lines appear to me, at least, distinct, and because of this to offer a logical grouping of recent work and a facile basis of orderly sequence for our consideration here For the sake of clearness in describing the several types of construction to which we must now direct our attention, it seems desirable to define at least two terms. The term "tandem-compound turbine" will be used to designate that type of construction in which a low pressure and a high pressure turbine are direct connected, one to the other, and the two used to drive a single generator (See Fig. 3;) the term "cross-compound turbine" will be employed to designate a unit employing a high pressure turbine direct connected to a generator, and one or more low pressure turbines each driving a separate generator in which the latter receive steam from the former and all operate together as a compound unit with the in-

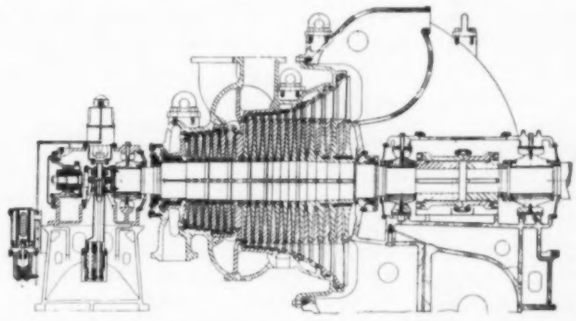

FIG. 6—Cross Section of a 40,000 KW, 1,800 RPM, 19 Stage Turbine Arranged for Re-heating Steam after passing 7th Stage.

dividual generators arranged to be connected electrically in parallel.

Prior to the beginning of the period with which we are now concerned—1924 to date—the largest simple turbine built was the 45,000 kw., 1200 r.p.m. unit, reference to which has already been made. This machine has recently been surpassed in capacity by a 60,000 kw., 1500 r.p.m., 20 stage single flow design, which is, I believe, the largest (in terms of capacity) simple single flow turbine placed in service to date. In general appearance it is not unlike the 30,000 kw., 1800 r.p.m. machines (Figs 4 and 5.) The

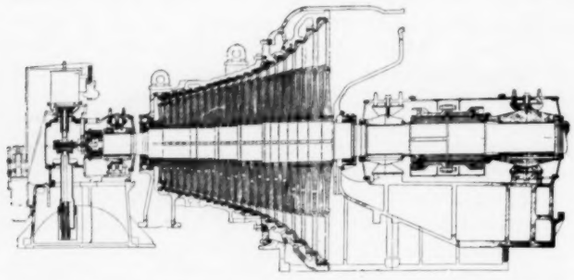

FIG. 7—Cross Section of a 50,000 KW, 1,200 RPM, 21 Stage Turbine.

turbine is direct connected to a 60,000 kw, 25 cycle generator. A 50,000 kw. 1800 r.p.m. 17 stage 60 cycle turbine-generator of this simple single flow, single casing type is now under construction, and, when completed, will probably be the largest 1800 r.p.m unit of its type. During the past year, there was completed and installed in the power station of our West Lynn factory, to obtain commercial operating experience with a unit of its size and speed, a 10,000 kw., 3600 r.p.m., 15 stage turbine-generator (see Fig. 8) which is the greatest capacity, 3600 r.p.m., machine we have thus far built. These three machines—the 60,000 kw., 1500 r p.m.; the 50,000 kw., 1800 r.p.m.; and the 10,000 kw., 3600 r.p.m. units—may be considered as representative of the most advanced practice and as embodying the most recent conceptions in large capacity single casing, single flow, turbine of the Curtis type.

Let us now turn our attention to the large compound units placed in service or on order since

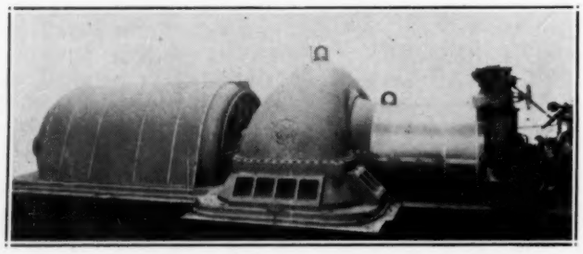

FIG. 8—A 10,000 KW, 3,600 RPM, 15 Stage Turbine Generator.

1924. For installation at the Miami Fort Station of the Columbia Power Company, two 45,000 kw., 1800 r.p.m tandem-compound turbine-generators (see Fig. 9), arranged for reheating the steam used after partial expansion, were built and are now in successful operation. The steam conditions under which they operate are essentially the same as those existing at the Philo Station—namely, 550/600 pounds pressure, 725 deg. F. temperature initial condition with reheating after partial expansion again to 725 deg. F. Each turbine is in two parts—a high pressure and a low pressure end or turbine—connected together through a flexible coupling (see Fig. 10 for the high pressure and Fig. 11 for the low pressure end.) The high

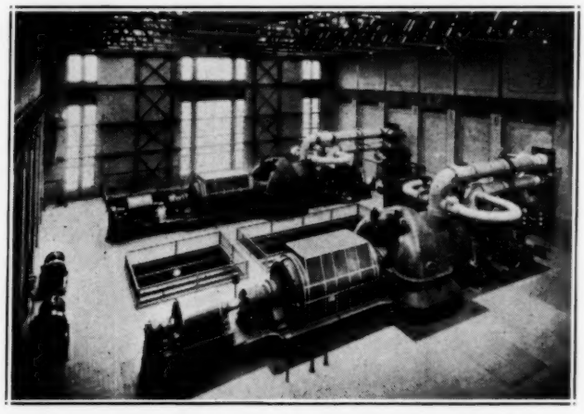

FIG. 9—Two 45,000 KW, Tandem-Compound Turbine-Generators at the Miami Fort Station of the Columbia Power Company.

pressure end contains 14 and the low pressure end 12 stages.

The steam is reheated after passing through the high pressure end and just before its entry into the low pressure end. The two ends or turbines, which form the complete turbine unit, are direct connected through a flexible coupling to a 43,000 kw. generator which in turn is connected to a 2000 kw. station service generator and two exciters.

Just prior to the installation of the two 45,000 kw. tandem-compound machines at the Miami Fort Station, the first large cross-compound set built by the General Electric Company was placed in service in the Crawford Avenue Station of the Commonwealth

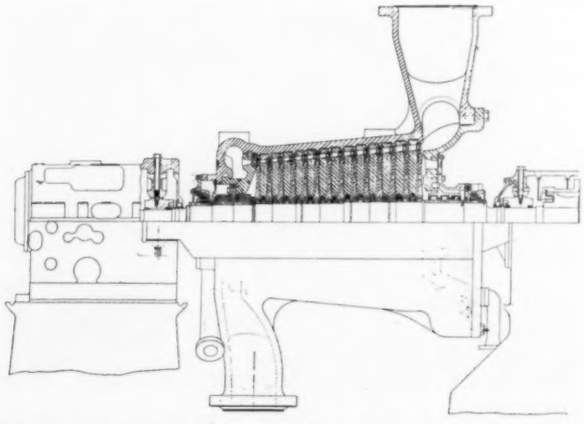

FIG. 10—Cross Section of High Pressure End of Turbine.

Edison Company (see Fig. 12). This was about the first of 1925. The set is rated 60,000 kw. and consists of a 10 stage, 1800 r.p.m. high pressure turbine (see Fig. 13) direct connected to a 17,000 kw. generator and a 2000 kw. station service generator and a 14 stage, 1200 r.p.m. low pressure turbine (see Fig. 14) direct connected to a 43,000 kw. generator. A unique feature of this machine is the method employed to

conduct the exhaust from the low pressure turbine. Instead of the exhaust hood being arranged to direct the exhaust vertically downward into a condenser located below the turbine in the conventional manner, in this machine it is split into two parts which straddle the turbine bearing and speed governing mechanism and discharge into two vertical surface condensers. This set, like the Philo and Miami Fort machines, has been designed for 550 pounds, 725 deg. F. superheat operation, and for the reheating of the steam after partial expansion. The reheating is done after the steam leaves the high pressure turbine. All these units are essentially base load machines, machines expected to operate with high economy at full load over long periods of time.

The next step in growth of turbine size came last year (1926) when a 77,000 kw. cross-compound set was placed in service in the same Crawford Avenue Station of the Commonwealth Edison Company. In its general appearance the new unit does not differ essentially from the 60,000 kw. machine. It has been designed, however, to carry fluctuating loads, and, so, no provision has been made for reheating. Steam of high pressure and superheat enters the high pressure turbine, flows through it and the low pressure turbine, thence into the condensers without interruption. The high pressure turbine drives a main generator rated 28,250 kw. and a station service generator rated 2000 kw.; the low pressure turbine drives a 46,750 kw. generator and large exciter.

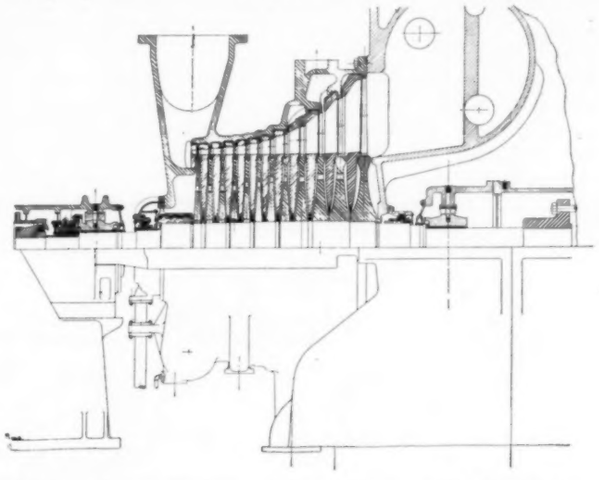

FIG. 11—Cross Section of Low Pressure End of Turbine of Fig. 10.

This concludes our brief survey of the large machines in service. You will be interested, I believe, in some of the large units now being designed and built, units whose sizes will dwarf the machines now in service as some of your present mill drives dwarf those of a decade ago. We are now manufacturing for the Southern California Edison Company a 94,000 kw. tandem-compound set to operate at 1500 r.p.m. It will consist of a single flow high pressure turbine direct connected to a double flow low pressure turbine. Both will drive directly a 90,000 kw. main generator, a 4000 kw. station service generator and two exciters. Also, we are building for the State Line Generating Company, for installation in their new plant on Lake Michigan near Hammond, Indiana, a unit of more than twice the capacity of the one under construction for the California Edison Company. It will be rated 208,000 kw. and will be designed for 600 pounds pressure, 730 deg. F. superheat, 1 inch vacuum and for reheating after partial expansion. Cross-compound type of construction will be employed. The unit will consist of one single flow high pressure turbine direct connected to a 76,000 kw. generator and two double flow low pressure turbines each direct connected to a 62,000 kw. and a 4000 kw.

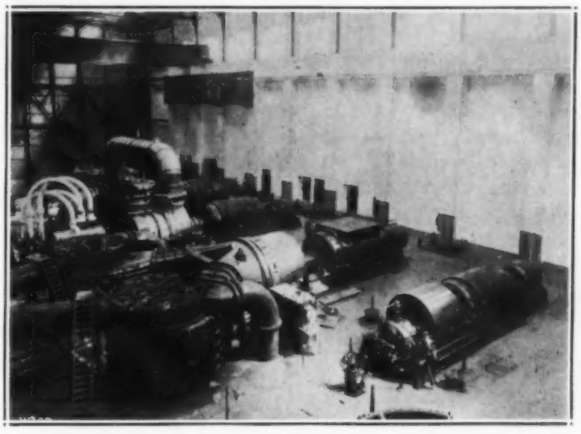

FIG. 12—60,000 KW, 1800/1200 RPM Cross Compound Turbine Generator (shown in foreground) in the Crawford Avenue Station of the Commonwealth Edison Company.

station service generator, thus making the combined output capacity of the three main generators 200,000 kw. and of the two station service generators 8000 kw., or 208,000 kw. in all. I believe this is the largest unit contracted for up to this time.

Now, just a brief word about the smaller capacity but highly important group of 3600 r.p.m. turbines. It is in this group that the interests of most of the industrial plant operators center, for their requirements are usually for 60 cycle turbine-generators in capacities not exceeding 10,000 kw. Most of the exceptions to this generality are to be found in the steel industry whose power needs are such, at the present time, as to justify the installation of 10,000 to 30,000 kw. units in many plants. A substantial number of the industrial processes require both electrical energy and steam. The alert operator appreciates the economies often possible through the coordination of the two services. This has led to a mounting demand for special turbines in the sizes below 10,000 kw. Never before was so large a percentage of non-condensing, automatic extraction and

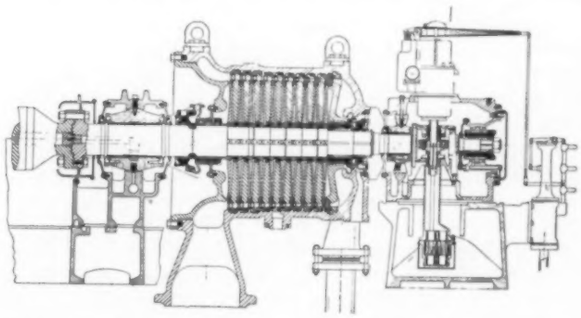

FIG. 13—Cross Section of High Pressure Turbine

mixed pressure turbines being manufactured; never before has the range of steam conditions been so great; never before have so many, so refined, and so intricate automatic governing mechanisms been required. Seldom have duplicate conditions been found in any two places. The knowledge of turbine design, some time ago, had progressed to the point where it was possible to build a more efficient turbine to meet any one condition than commercial considerations could justify. Until lately, to do this a large developmental expense must have been incurred and charged against the specific machines to which it originally applied. The result would have been extremely expensive machines—machines whose cost often could not be justified by the advantages inherent in them. To charge all the developmental expense against such special machines was equitable and necessary for there was little evidence to lead

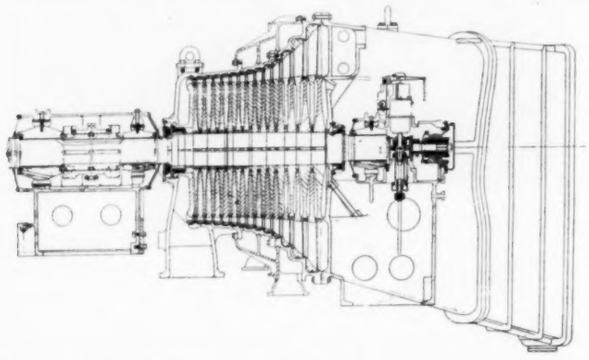

FIG. 14—Cross Section of Low Pressure Turbine shown in Fig. 13.

one to believe that the one or two turbines of any single order ever would be duplicated or that any appreciable number of the special parts again could be used. Briefly, the major problem confronting turbine designers and manufacturing specialists, in connection with machines of the sizes now under consideration, has been to evolve means of building a line of turbines to fill the present range of requirements at reasonable cost in which can be incorporated most of the present known possible improvements. In the study of this problem it was early concluded that a solution must be realized through machine methods of manufacture, large scale production and the standardization of parts insofar as possible throughout the whole range of types and sizes. With these principles as guides, there has been developed during the past few years a comprehensive line of standardized, interchangeable turbine parts—governors, high pressure ends, exhaust hoods, wheels, diaphragms, extraction mechanisms, etc. These can be made in quantities and stocked for used as required, thereby realizing the benefits which accrue from a large scale standardized production. All have been designed to realize the widest range of application and to lend themselves to assembly together with the least number of special connecting parts. With these standard parts it is now possible to design and build quickly—and at a reasonable cost—an efficient and reliable turbine to meet the most exacting and unusual requirements. A comparison of the two turbines of illustrations, Figs. 8 and 15, will reveal the possibilities inherent in the principle of parts standardization. Fig. 8 shows a straight condensing turbine designed for high initial pressure and low vacuum which has been assembled with a 10″ (throttle size) high pressure end and a 105″ (exhaust size) exhause hood. Fig. 15 illustrates a smaller machine, smaller in terms of kilowatt output, arranged for condensing operation and automatic steam extraction at two pressures. In its construction have been used a 12″ high pressure end and a 60″ exhaust hood. Note the similarity in general construction and of the detail parts of the two machines.

A review of this kind would not be complete without some mention of the more advanced experimental work going on at present. Two installations, each largely an experiment two years ago—but certainly one, if not both, now a proven commercial reality—warrant our attention and deserve more than the cursory treatment space necessitates here. The first of these is the development of the 1200 pound pressure turbine; the second, the mercury-steam binary vapor cycle*, or, as it is better known, the Emmet mercury-vapor process. A little more than a year ago 3000 kw. turbine-generator designed to operate with steam of 1200 pounds initital pressure and to exhaust against 350 pounds back pressure was completed and placed in the Edgar Station of the Boston Edison Company. It was admittedly an experiment when installed. Never before had boilers, piping, fittings and turbines been built for anything approaching this pressure in capacities large enough to be considered seriously for modern generating station service. The experience gained with this

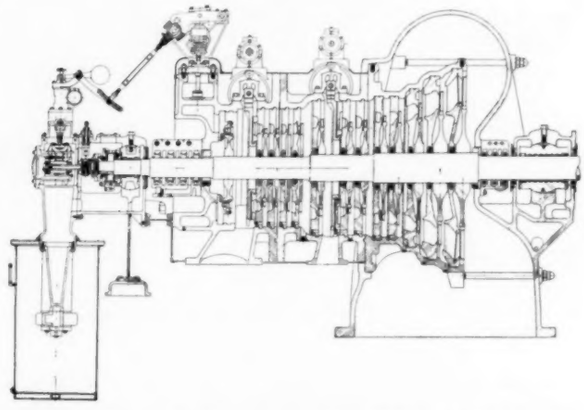

FIG. 15—Cross Section of a 3600 RPM, 13 Stage Turbine Arranged for Condensing Operation and Automatic Extraction at Two Pressures.

initial installation has justified the expectations of its sponsors. The essential problems inherent in the generation and utilization of steam at this pressure have been solved. We can hardly longer look upon it as an experiment, and we may expect consequently to see more of these high pressure installations as result of the generous pioneer work done at Boston. In support of this conclusion, or prediction, I offer the fact that during the closing months of 1926 there was placed in service at the Lakeside Station of the Milwaukee Electric Railway and Light Company a 7000 kw. turbine-generator designed to receive steam of 1200 pounds pressure, 725° F. total temperature, and exhaust it at 300 pounds pressure for use—after

*See: "The Emmet Mercury-Vapor Process," by W. L. R. Emmet with appendix, by L. A. Sheldon, A. S. M. E. Transactions page 253, 1924.

superheating again—in the existing condensing machines.

An experimental mercury turbine and boiler installation was placed in service at Hartford, Connecticut, several years ago to study the performance of the apparatus involved in the combined mercury and steam cycle under commercial operating conditions. The equipment has been variously rated from 1500 to 2000 kw. capacity. The results obtained with this installation have been very gratifying. Much has been learned and progress is being made. It is still too early to attempt to predict accurately the future of the mercury-steam cycle as a commercial principle for power generation. This much, however, can be said: no insurmountable difficulties have yet been met, and, if past experience means anything, the system has an important future.

Before ending a paper of this kind, it is not uncommon for the author to assume a prophetic role and anticipate the future. I shall avoid any detailed predictions, preferring to content myself primarily with the exposition of the accomplishments just presented. About all that one can say for the future with certainty about turbines is that mechanical designs will be improved, greater efficiencies will be reached, larger units will be built, the average thermal range of all machines will be extended, more steam re-heat installations will be made, some special cycle—like the mercury-steam cycle—will probably be introduced. As past development has so far surpassed the most optimistic expectations of observers, one has the feeling that in making even these general predictions, he will err. But he will probably err on the side of conservatism, and, because an error on the side of conservatism is not so bad a fault after all, he will not be entirely without comfort.

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*Ductless Electric Power Cables**

By C. F. HOOD†

IT is my understanding that this body of Engineers is particularly interested in a discussion of ductless cables for power transmission and distribution. Such cables are built up much the same as other types of power cables, with the exception of the added special protective coverings and appliances. I propose, therefore, to trace the methods of manufacturing and adaptability of the principal groupings of power cables with special reference to ductless cables.

In the consideration of various types of electric wires and cables, it may not be amiss to consider briefly the fundamental problems with which we are concerned.

In general, we are dealing with two substances of widely different characteristics, i e., Insulators and Conductors. In the present state of the art and our knowledge of materials, we do not know of either a perfect conductor or a perfect insulator. All known conductors have some resistance and the best insulators have appreciable conductance for an electric current.

All present day materials are to some extent conductors of electricity, and, in general, obey Ohm's law, that is, when subjected to a voltage, a current will flow which is proportional to the impressed voltage divided by the resistance of the circuit.

It is our problem, as Engineers and Manufacturers, to apply the proper amount and type of insulating material to a conductor of a size and construction best suited for the customer's requirements. This insulated conductor, or group of such conductors, must then be protected against mechanical injury and chemical action to which it may be exposed.

Conductors.

Nature has provided an abundant and relatively cheap conducting material in the form of copper. This metal is high in conductivity, is ductile and easily worked and drawn into wire.

Copper wire bars, as received by the mill, are normally 4″x4″x4′, weighing approximately 225 lbs. These bars are heated to the proper rolling temperature and passed through Billet and Rolling Mills by means of which the metal is reduced to a rod, usually 9/32″ or 1/4″ O. D. From this point on, the metal is worked cold and is drawn by means of continuous wire drawing machines to any size desired.

The drawing of copper increases both its tensile strength and electrical resistance and reduces its ductility. For most purposes it is desirable to anneal the completed wire, which process relieves the internal drawing strains, lowers its tensile strength and restores its electrical conductivity and ductility.

A conductor in a wire or cable may be one individual solid wire or grouping or arrangement of a number of such wires, depending on the amount of current to be carried, the flexibility required, etc.

The cross section of the conductor may be round, sector or "D" shaped, or constructed with a rope center or hollow core, depending on the requirements it is to fulfill.

From a standpoint of conductivity, it is very essential that the metal be free from alloys or impurities, as a very small portion of a foreign substance will very materially reduce the electrical conductivity. For that reason electrolytic copper is very widely specified by the Electrical Industry.

Insulators.

In the field of insulators suitable for the purpose of electric wires and cables, we have a variety of materials and compounds now in common use, the most prominent of which are cotton, rubber compound, varnished cambric, saturated insulating paper, enamels, waxes, oils and saturating compounds.

It is in the selection and use of insulating materials that the manufacturer has been able to make the greatest progress in meeting the ever increasing

*Presented at Pittsburgh, Pa., January 15, 1927.

†Operating Dept., American Steel & Wire Company, Worcester, Mass.

demands for cables that will be suitable for the higher and super-power transmission voltages.

The value of an insulator is largely dependent on the following characteristics:

1. Voltage breakdown value.
2. Insulation resistance.
3. Electrostatic capacity (or capacitance).
4. Flexibility.
5. Ageing qualities.

It has been only a few years since 6.6 K.V. was considered to be the highest limit of voltage for cables. Today we are making multiple conductor cables for 30-35 K. V. and in one or two cases for 44 K. V. Single conductor cables for 66-75 K. V. between phases, are in successful operation, and at this time two large Utility Companies are installing a 132 K. V. underground system.

Impregnated paper insulation, in spite of its disadvantages, is at this time the most promising insulator for the higher voltages, and it is with this type of insulating material most of the research and development is being done.

One of the first radical changes was to reduce the power factor and dielectric loss in paper insulated cables. The following tabulation is representative of present day results as compared with a cable of some years ago.

We recently had the opportunity to test a piece of cable which had been in service for about 15 years and was still carrying its rated capacity. The results and comparison with present-day cable are:

DIELECTRIC LOSS PER FOOT

Temperature Deg. C.	Watts (Old Cable)	Watts (New Cable)	
20	0.38	0.05	Watts per foot at 60 cycles.
40	0.69	0.07	
60	1.30	0.13	
80	3.60	0.24	
100	7.50	0.47	

POWER FACTOR %

Temperature Deg. C.	Old	New	
20	5.0	0.60	Power factor at 60 cycles.
40	9.0	0.90	
60	17.0	1.75	
80	46.0	3.10	
100	78.0	6.10	

Dielectric loss is the loss due to the voltage stresses present in the dielectric or insulating material. It is independent of the current but varies with the frequency, temperature and the square of the voltage up to the point of ionization. The power factor of the charging current varies in the same manner, except that it is independent of the voltage up to the ionization point.

If the square of the voltage applied to a cable under test is divided by the Watt loss, the result is an equivalent A.C. resistance. For a definite temperature this value will remain practically constant up to a certain point, but beyond this the losses increase more rapidly than the square of the voltage. When this condition is reached the cable is said to be ionizing . It is generally conceded that a cable operated materially above its ionization point will have its useful life reduced.

Breakdown voltages have at the same time been increased. It is now possible to obtain rupture voltages of 600 to 700 volts per mil on short lengths of cable, as compared with 250 volts per mil some time ago.

With the obtaining of lower losses and higher breakdown values, the cable is required to meet severe bending and deformation tests.

Commercial research and technical University Laboratories are working to perfect the insulating materials with which we are dealing and at the same time are searching for new and better ones. The results of such labors are passed along to the purchaser and user of cables in the form of a more reliable product suitable for the ever increasing demand of higher and higher transmission voltages.

Protective Materials.

To protect the insulation from mechanical injury, the entrance of water, chemical action, and to afford a means of taking any laying strain off the conductor and insulation, various materials and combinations are used. These may consist of one or more thoroughly saturated and waxed cotton or jute braids, lead covering, or a combination of lead, jute and armor, either flat band or round, and an outer covering of jute. In some special constructions a jacket is built up of heavy reinforced rubber tapes vulcanized together. An outer braid of fine steel wires is a method of armoring cable for certain uses on board ships and where abrasion is a factor.

In the power cable group, the insulating materials commonly used are, vulcanized rubber compound, varnished cambric and impregnated insulated paper.

Rubber Covered Wires and Cables.

One of the largest groups of power and distribution wires and cables are those insulated with a vulcanized rubber compound.

To prevent any chemical action between the sulphur in the compound and the copper conductor, all conductors of rubber covered wires and cables are tinned.

In the case of an insulation to be made up of vulcanized compound, we must start with the raw rubber. While there is a large variety of rubbers, the two most common to insulating practice are fine Para and smoked sheets. The first mentioned is a wild rubber gathered by natives in the forests of the upper Amazon. The sap or latex of the rubber tree is coagulated on poles over nut fires, the smoke having a preservative effect. The biscuits of crude rubber are shipped through the port of Para, from which the name is derived. When received at the factory, the biscuits of rubber are thoroughly washed and sheeted on corrugated steel rolls. This washing is necessary to remove all foreign matter, such as leaves, twigs, grass, dirt, etc. Raw rubber will take up about 15 per cent of moisture, so the sheeted rubber must be hung in drying rooms for a period of at least thirty days. In the uncured state rubber is easily affected by changes of temperature, and decomposed by sunlight and high heat. For these reasons it is kept in darkened compartments, insofar as practical.

Plantation rubber is received in the form of thin smoked sheets, baled together. This latex is secured from cultivated trees and is coagulated in large vats or tanks by means of a small per cent of acid; it is

then sheeted and smoked. Due to the method of handling it is free from foreign matter inherent in fine Para. As far as quality of finished product is concerned there is practically no choice between these grades, although the use of fine Para has very materially decreased in the last five years. After the drying process necessary to Para rubber is completed, the two grades are handled in the same manner. The average insulating compound contains between 30 and 40 per cent of pure rubber, the remaining 60 or 70 per cent being made up of mineral fillers with sufficient sulphur to insure proper vulcanization.

In compounding rubber it is first placed on a rubber mill consisting of two horizontal rolls revolving at slightly different speeds. When the rubber is thoroughly masticated, the mineral fillers are added and the whole kept on the mill until thoroughly mixed. The mixed material is of about the consistency of heavy dough, it being plastic, absorbent, cohesive, slightly elastic and easily moulded. It is then ready to go to the insulating room. The process of mixing and compounding is not a process of adulteration by any means, but, on the other hand, makes for a superior dielectric. It will be realized that great care, experience and knowledge are necessary to insure proper compounds.

In general, two methods of insulating are used, the strip and tubing. The strip machines require the compound to be sheeted out on calender rolls and then cut in strips of the desired width. These strips are fed through guides into grooved circular cutters running tangent to each other, which form and compress the compound around the conductor, cut off any excess, and make a tight continuous seam. The number of covers which are put on any conductor depends upon its size and operating voltage. This method of insulating is particularly adapted to conductors of large circular milage and to the best grades of insulating compound.

The second method we term tubing. A machine with a revolving worm in a close fitting steam jacketed cylinder is employed. The rubber compound is forced under high pressure into a chamber at the end of the worm. The wire to be insulated enters the chamber through a back die and at right angles to the axis of the machines, and leaves through a die having a diameter equal to that over the insulation required. The force of the compound going through the die carries the copper wire with it, except wires with thin walls, when some tension is used. This method gives a seamless coating of compound moulded on at high pressure.

After being insulated by either method, the wire is taken up on either a vulcanizing drum or in pans. Talc is used to prevent injury and the wire sticking together in the panning process.

To secure vulcanization the insulated conductors are placed in large tanks and subjected to live steam temperatures ranging from 240 to 280 deg. F. for periods of from 45 minutes to one and one-half hours, depending on the particular compound being vulcanized. The process causes the sulphur, rubber and some of the other ingredients to enter into a chemical change, with the result that the soft plastic compound has become elastic, firm and of good tensile strength, and it is no longer easily affected by changes in temperature, or by exposure to heat and sunlight. This operation requires close supervision and thorough experience. An otherwise good compound may be rendered practically useless by improper vulcanization.

All rubber wires and cables then go to the testing department where they are immersed in water for from 12 to 48 hours, at the end of which time voltage is applied between conductors and ground, equal to 2½ or more times the working potential. Measurements for insulation resistance and for capacitance are made after the voltage test. These tests insure that nothing but material in accordance with customer's specifications or our standards is furnished to the trade.

After being passed by the Testing Department, single conductor wires and cables are usually given a protective covering of tape, cotton braid or lead, or a combination of these. Multiple conductor cables are stranded together with fillers to round out the whole and then given some kind of protective covering, as in the case of single conductors.

Varnished Cambric Cables.

In the construction of varnished cambric cables, strips of varnished cambric from ¾" to 1½" in width and 5 to 12 mils in thickness are wound spirally about the conductors in sufficient number to give the thickness of dielectric required. The tape itself is prepared by applying and baking several coats of insulating varnish onto sized cloth, giving a smooth, glossy, flexible tape of high insulating value. The average breakdown for varnished cambric is about 1000 volts per mil.

In applying these tapes, a non-hardening compound is pumped between layers which seals the dielectric from air and moisture, and serves as a lubricant when the cable is bent. This type of cable is particularly adapted for use in power houses and sub-stations, oil switches, etc. It can be used in dry places without a lead sheath.

Paper cables are insulated in about the same manner as varnished cambric cables, except that strips of manila or wood pulp fibre paper .005 to .007" in thickness are used and no compound is put between layers at the insulating machine. The selection of high grade paper is essential to a good cable, and this paper is carefully tested by our laboratory before being used in the factory. After the cables have been made up, either single or multiple conductor, their treatment is quite different from either rubber or varnished cambric cables. The insulating paper as received and applied to the conductor contains on the average about 7 per cent of moisture, and in order that the cable may have low losses and not fail in operation, all traces of air and moisture must be removed from the insulation. To accomplish this end, the cables are placed in large tanks with steam coils around their periphery. Heat is applied for a number of hours with the cable exposed to the atmosphere. The cover on the tank is then closed and a high vacuum applied to the contents of the tank. The vacuum is maintained until there is no evidence of moisture and then for a few additional hours as a safety factor. The hot saturating compound is then drawn into the tank and when the cable is completely covered, air pressure is applied so as to force the compound into the paper insulation. The compound is then allowed to cool to room temperature, when it is about the con-

sistency of jelly. The dielectric value of paper insulation is very dependent on the impregnating compound and saturating practice employed.

The next manufacturing operation is to put the cable through a hydraulic lead press which forms a close fitting, continuous lead pipe over it; this lead covering seals the insulation from air, moisture, gases, and other agents which would quickly cause failure if allowed to come in contact with the paper insulation.

Testing.

In order to insure to the customer that the cables are satisfactory for the service intended, all wires and cables are given a process of final factory inspection and test. Normally this test is a voltage two and one-half times the rated operating voltage of the cable applied for five minutes. In the case of recent specifications on paper insulated cables, the test values have been increased to 165 volts per mil of insulation.

Measurements of insulation resistance and of capacitance are also made and the results must be within predetermined limits for the type and size of cable under test. In the case of all high voltage paper cables, tests for power factor, dielectric loss and ionization are also made.

In certain cases tests are now being made on the paper cable compound itself to determine if there is any change in the compound under electrical stress. To accomplish this, a film of compound is placed between glass plates and stressed in the neighborhood of 600 volts per mil. This test is normally continued for 72 hours. At the end of the test period a perfectly satisfactory compound should show no change of structure.

The great majority of paper cable specifications now require that a bending test be given samples of cable before acceptance by the purchaser. These tests normally consist of cooling the sample to a minus 10 deg C. after which the cable is given four bending cycles around a form 12 times its own diameter. The cable is then expected to show few, if any, torn papers.

For test requirements and for factory research purposes we have found it necessary to install testing equipment capable of 700,000 volts A.C. and a Kenetron outfit which will be capable of 300,000 volts D.C.

Ductless Cables.

For the underground transmission and distribution of large units of electric energy, the general American practice is to employ duct systems. Such systems lend themselves quite well to the requirements of our customers, but are expensive to install or to enlarge. To provide a suitable but less expensive distributing system for scattered districts and for boulevard and parkway lighting, a ductless or Parkway cable was developed, which can be buried directly in a trench dug in the ground. Due to the ease of installing this type of cable and its lower total cost, as no ducts are required, there has been a steadily increasing demand for it.

European practice, contrary to that in America, is to bury practically all power cables directly in the ground.

In addition to eliminating the cost of a duct system, there are other noteworthy advantages in cables of the ductless type, chief of which are better heat radiating abilities and corresponding increased carrying capacities. When more than one cable is banked in a duct system, the normal rating of the cable should be reduced to insure that it is not operated at an excessively high temperature.

When there is more than one cable in a duct system, the rated capacity of the cables should be multiplied by a factor as given in the following recommended table:

No. of cables	Factor
1	1.00
2	.90
3	.83
4	.77
5	.72
6	.68
8	.61
10	.55
12	.50

When cables are buried in the ground in direct contact with the moist soil, better thermal conductivity is obtained than from dry ducts.

With this type of cable it is quite easy to avoid obstacles that may be in the way, and to effect river or stream crossings. Such cables may be insulated with rubber, varnished cambric or impregnated paper, as previously outlined. They are invariably lead covered, in the case of varnished cambric or paper insulation, and usually so in the case of rubber insulation.

Cables of this class can be and are built for as high voltage values as other types of power cables, i e., up to 33,000 and in some cases 44,000 voltage between phases.

Due to the magnetic losses and inductive effect, when armored single conductor cables are used, it is desirable to employ multiple conductor cables wherever possible, to the end that all conductors may be encased under the same armor. A special type of cable, wherein three leaded single conductors are cabled together and armored overall, has been developed for the underground transmission of the higher 3-phase voltages.

The only difference in the makeup of the ductless cable is the methods used for mechanical protection. This protection is usually obtained by applying a tarred jute bedding over the lead sheath, after which is applied a steel armoring. This armoring may be of various types, depending on the service which is to be required of the cable. If the cable is liable to be subjected to lateral strains or tensions, then round wire armoring is used, which armoring takes all strain and stress from the cable itself. This type of armoring is always employed when the cable is suspended in a shaft, for submarine work, or any other condition when an installing or working strain is encountered.

When the cable can be laid in a trench, where no heavy strain is encountered, the round wire armoring is replaced with either a flat band armoring or a form of Armorlokt armoring.

In the case of flat band armoring, two steel tapes, usually .020-.030 thick, are wrapped spirally over the jute bedding. A suitable space is allowed between each tape to give flexibility, and the gaps of the first tape are covered by the second one.

The Armorlokt protection is given by a single steel tape applied by means of a special taping head which forms and locks the tape on itself, making a continuous but flexible metal hose. After the armor application, the cable receives a final tarred jute covering which acts as a protector to the armor itself.

Ductless cables recommend themselves particularly for use in steel plants where it is necessary to transmit power between buildings or units and can be used to replace pole lines throughout the plant territory. Such underground construction makes for safety, permanence of installation and for improved appearance of plant property.

A few words of caution should be said regarding the installation of ductless cables. Care should be taken to avoid runs through fills of sand, ashes and the like, which, when dry, have a high heat insulating value and may cause, even for a single cable, abnormally high operating temperatures and resultant cable failures Care should also be taken to avoid, if possible, locations which may be saturated with active chemicals which would ultimately shorten the life of the cable.

The trenches need be only deep enough to completely cover and protect the cable. Normally, 18 inches to 2 feet is a sufficient depth.

It is good practice to cover the cables with a board or plank, which will be found previous to striking the cable, in case of workmen digging in the yard. The armor acts as a mechanical protection to the cable but in case of a direct blow from a pick, damage to the cable might result and the board or plank covering would serve as an additional safe guard.

Joints.

The making of joints in electrical cables, particularly those for the higher voltages, is work which should be undertaken only by experienced jointers. It has been found that the methods and practice for making joints on cables, say up to 20,000 volts, is by no means satisfactory for cables operated at voltages higher than that figure. As the voltage of the cable increases, the skill and reliability of the jointer as well as the proper design of the joint, are factors of increasing importance. The field of cable jointing is so large that no attempt will be made at this time to discuss this feature in any detail. In case the purchaser has not a trained personnel capable of making joints, he should call upon the factory or upon the local public service company, either of which will undoubtedly be able to take care of or assist in the making of the proper joints.

DISCUSSION

A. F. Hovey*: Would commend the author of this paper for presenting this matter in such accurate detail. As noted, there are two schools of Engineering Practice, one the Ductless Cable School, as is so generally adopted abroad and the other the Duct Cable School so uniformly adopted in this country. It is not possible that each of these schools are 100 per cent correct and therefore there must be cases where the opposite type of cable could be used to greater advantage.

Much can be said as to the economy of construction in the case of ductless cables and also the higher current carrying capacity of this type. There is a further advantage in operation and maintenance wherein a repair or change can be made in the cable by the installation of a splice instead of the usual requirement of a new section and the remaking of two splices in the conduit system largely used in this country.

At this time of a possible failure, either mechanical or otherwise, we are apt to assume that if it occurs in a section, a new length of cable will be required and at least two joints be remade. In the ductless type of cable, accurate locations of the fault can usually be made and the cable dug up and the cable made ready for operation by the making of one splice.

Local conditions largely indicate the choice of these two systems and in the writer's experience where a definite load between two points which has little likelihood of being increased, it was carried in an adequate number of ductless cables from the Power Station to the Sub-Station and considerable expense has been saved in the installation of such systems.

The note as to the advisability of avoiding ashes, etc., in laying ductless cables has been offered as a caution in this paper. Believe if equal care is taken in the selection of the proposed location of the ductless type of cables to that which might be used if conduits and manholes were installed, then there would be better cooling conditions for the buried cable, which is of high importance in either case to maintain the highest possible current carrying capacity. It is usual to excavate ample trenches and fill with good earth where installation is in slag or ashes.

R. F. Chaffin*: Sometimes the extension of a plant goes out in a direction after it is once started that was not intended in the first place. At our plant we have several miles of underground transmission and in 12 or 13 years I do not know of having a joint failure. We have lost a cable or so due to the fact that there had been a steam line run over the top of the duct and we would lose a cable from that cause, but otherwise they have been very successful.

M. J. Garrahan†: The choice between duct and ductless cable depends on local conditions. As the author has said, it has been the common European practice to use ductless and the common American practice to use duct system. However, there have been high voltage ductless systems in successful operation in this country for quite a few years, one of them being in Detroit, operating at 24,000 volts. This installation being ten (10) three-conductor paper insulated cables with lead sheath protected with light steel armor and we put that ductless cable in there for the reason we had to cross swampy ground and could not install duct system. Afterwards a duct system was installed over ductless cables. The ductless cables are still operating with the duct cables over them.

W. E. Miller‡: I would like to ask the author what he would recommend to a steel mill man where they don't have anything but ashes and cinder fills?

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*Supt., Steam & Elect. Dept., Pittsburgh Crucible Steel Co., Midland, Pa.

†General Electric Co., Schenectady, N. Y.

‡Supt., Elec. Dept., Bethlehem Steel Co., Johnstown, Pa.

C. F. Hood*: If you have sufficient room, allow as much spacing as you can by increasing the width of the trench and introduce soil that will dissipate the heat from the cable. Another scheme would be to put in extra copper and run the cable below its normal operating temperature. Water can be used if available. With the duct system water can be run through one of the ducts to cool the others.

W. E. Miller: Would you recommend making trenches larger and concreting the cable to protect the armor?

C. F. Hood: The armor does not require concrete protection. It may be put in to protect cable under conditions where you are sure there is going to be digging. The armor is ample protection for cable. You can pour a thin layer of concrete over the trench after it is made.

W. E. Miller: I have in mind a coke plant yard where you have acid conditions seeping into the ground. If it is filled up with earth when this acid solution from by products saturate the ground the armor would eventually be eaten up. I would like to know whether you would recommend concreting around the cable in order to protect the armor.

C. F. Hood: You might as well go to duct system, say fiber duct imbedded in concrete.

W. E. Miller: Life of conduit is very short around a coke plant.

C. F. Hood: Fiber conduit will readily nullify any effect of acid.

W. E. Miller: It is not much good for railroad yards.

John C. Reed†: It will be 23 years next summer since I laid a submarine cable across the East River at the time of building the Blackwell Island bridge. That consisted of two cables each 500,000 cir. mil., laid in a manner somewhat like we saw in the picture this evening. They were laid from the New York shore over to the island for the purpose of conveying power to the island and back to the shore. Large power plant on the shore. They were building the middle span and had an air compressor on New York side. That worked beautifully while it worked. We had two signs on each side of the river that there was a cable crossing there, but so far as the laddies who sailed the blue seas were concerned they might as well not have been there. Some fellow would come down East River and catch one of these cables with his anchor and I would get a hurry call to come to New York and fix up these cables. I got a factory man to fix up the cable. The trouble was we would get the wrong gang working there and I figured we wouldn't get any power, but to my surprise we got very good voltage on the New York side. That bothered me at first and could not quite see where it was coming from until I learned the Standard Oil Company had a pipe line across there which was helping out considerably.

Another experience with underground cable was in steel yards where I laid ducts for the operation of ore bridges. I thought it a good job, but after some years one of those cables grounded and when we pulled it out, found that the weight of the ore on those ducts pushed them down into the ground.

*American Steel & Wire, Worcester, Mass.

†Elec. Eng., Bethlehem Steel Co., Steelton, Pa.

This cable is very similar to what we term parkway cable. Had experience in laying about five miles of that cable this summer in connection with street lighting. For Mr. Miller's benefit, the whole of Front street has four feet of fill, most of which is ashes and cinder. In years gone by that question of how long that armor would last bothered me. I finally decided to concrete that trench, making it of sufficient size, 4" to 6" around that cable. I have faith that it will last.

James Farrington*: I would like to ask what is the minimum distance that the ductless cable could be laid with safety? Also the relative cost of the ductless over the regular duct, if you have to haul dirt to cover it up?

We laid one ductless system. When it started out it was 14 feet in the air. We had 23 foot fill. That was in coke works and have had one failure due to the same condition Mr. Miller spoke of, hot steam and vapors from by-product building getting through the openings in the concrete and the current of 250 volt circuit got through, making it necessary to pull them. If we had left it there we would have had a lot of dirt. I would like to know the relative cost of those systems.

C. F. Hood: The answer to the first question depends on the size of the cable, the load, and the amount of heat to be dissipated. With power cables the deciding thing is amount of heat to dissipate and nature of the soil. As a general rule for a big power cable we like to see them spaced 3 and sometimes 6 feet, that is for a cable carrying a large amount of power.

So many things enter into the question, such as size of cable, cost of labor and cost of material, it is difficult to give you an answer as to what that would cost; but it might cost you as much with a ductless system under severe conditions as it would conduit system.

A. J. Standing†: There is very little that I can add especially on cable making. We have at times been confronted with the same problem of corrosion of conduit in cinder fills referred to by Mr. Reed and Mr. Miller and like them have had recourse to clay fills or in some case concreting of the conduit.

I want particularly to call attention to the very complete and instructive paper we have listened to this evening. I am sure that we all have gained considerable information about an important branch of the electrical industry which makes possible the distribution of power under most unusual conditions.

I hope that sometime I may be in a position to see the manufacturing process as described tonight.

George Black‡: What is the usual spacing of manholes?

C. F. Hood: In the case of ductless cables manholes are not necessary. It is usually not good practice to pull heavy power cables then wire through 500-600 feet of duct. This limitation together with the convenience of installing manholes in city streets determine their location. The average manhole lengths are about 400 feet.

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†Supt., Elec. Dept., Saucon Plant, Bethlehem Steel Co., Bethlehem, Pa.

‡Elect. Supt., Carnegie Steel Co., Clairton By-Product Coke Plant, Clairton, Pa.

George Black: We have probably 12 or 15 layers of cable in coke plant service and we have had only one failure due to the lead being attacked.

M. W. Ghen*: I have enjoyed this paper very much and while I do not see how we will use parkway cable in Pittsburgh streets, I will say it has its application. I think it is probably more interesting to you men in the steel mill than power companies in a congested district like this.

I would like to ask how many layers of varnish is required to build up varnished cambric?

C. F. Hood: About 6 to 8 layers of varnish. It goes through a dipping and baking process after each varnish application until the proper thickness is obtained.

F. W. Cramer†: I would like to ask Mr. Hood a question in regard to cables. Instead of laying them on the ground, would like to put one down a mine shaft, 600 feet cable. About four years ago we wrote to all the prominent cable manufacturers on how to hang the cable. We did not get much of an answer back. It is a 600 foot drop; weight of cable about 2¼ pounds to the foot. Has there been any information collected on how far you can hang these cables in a shaft?

C. F. Hood: The stress that the armor wire will stand is the limiting factor in determining the length of cable that can be suspended.

F. W. Cramer: What would you specify; what supports?

C. F. Hood: We would send one of the engineers out to look it over to see whether it is possible or not. We have put down shaft cables, but each one is a problem by itself; whether it will hang free or be supported on the way down. If you come to a suitable point you can make a secondary anchorage, but if hanging by dead weight you have another problem. Each situation is a problem in itself. What may be all right for one job may not work for another at all.

R. B. Davenport‡: We have had some parkway cable in for about 15 years without a failure, for 250 volt D.C. I am interested in the higher voltages just now. What is the maximum length you could run a cable 350,000 cir. mil., 6600 volts, in one piece?

C. F. Hood: 1,000 to 1,200 feet.

J. S. Murray§: We do not use any parkway cables at the Toronto Plant. Most of our circuits run in fiber and steel ducts, incased in concrete and consisting of lead cable, varnish, cambric covered cable with weather proof braid for 2300 volt service. We make periodical tests and plot curves, on insulation resistance of important circuits, by means of Biddle bridge megger and we have anticipated possible cable failures in advance on several occasions. This bridge megger also permits the making of varley loop tests, with the purpose of showing the exact location of defects and failures.

Mr. Cramer asked Mr. Hood regarding the method of supporting lead cables in mine bore holes and as a point of information, I am showing a sketch indicating the method of installing a lead cable which I have used in several mine installations in Eastern Ohio fields.

E. W. Oesterreich* As far as the application of ductless cables in power plant work is concerned, I cannot tell you very much about it, inasmuch as this type of construction has been used to a very small degree. In central station distribution and transmission work, it is almost impossible for us to put a cable into the ground without facing the possibility of having to replace the cable with one of larger capacity in a short time. Our systems are growing so fast that we are constantly enlarging the size of the cable feeders and mains.

We have considered ductless cable, but several things have, up to the present, made us decide against them. The difficulty of locating trouble and the cost of making repairs is one of the greatest handicaps. In some difficult cases, it would even be necessary to make excavations and tests cuts. For steel mill applications, such as those discussed this evening, this would be a very serious objection. Cables which are installed today in an apparently open area, may be under a pile of coal, scrap iron, or other material a short time after installation, and the problem of maintenance would then become very serious. With a system of ducts and manholes, only the manholes would have to be kept accessible and the defective sections of cable could be replaced.

For street lighting systems, ductless cables have been applied satisfactorily. The loading of the cable is negligible and they can be installed within reach of the surface of the ground. In some installations, it hasn't even been necessary to dig a trench. The cable is attached to the rear of a special plow which forms a hole in the ground approximately 12 inches below the surface and the cable is drawn into this hole as the plow is pulled forward.

For central station use, some of the European operating companies are using armored cable. The number of cables to be brought out from a generating station is in some cases quite large and the result of the concentration of these cables is a reduction in current rating. We rate our cables higher than the Europeans in spite of the fact that our cables are installed in conduits, which is not as favorable a condition from a heat dissipation viewpoint as cables buried directly in the ground.

I want to compliment the author upon the very complete digest which he has made of cable design data. Of all of the advancement made by manufacturers of electrical equipment, probably that advance made by the impugnated paper cable industry has been one of the greatest in recent years. Losses have been reduced, safe operating temperatures have been increased and a more complete understanding of cable operation is now available.

H. E. Lawrence† As Mr. Hood was talking about putting a plank over parkway cables, several failures that happened in and around his own plant with older installations came into my mind. One of the first underground cables that was put in the plant, before parkway cable was thought of, that old lead covered cable was down there with a plank over it. The foreman of the yard labor gang had been given instructions to tell all of his men

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†Asst. Supt., Elec. Dept., Bethlehem Steel Co., Johnstown, Pa.

‡Elect. Supt., Carnegie Steel Co., New Castle, Pa.

§Elec. Supt., Follansbee Bros., Toronto, Ohio.

*Supt. of Distribution, Duquesne Light Co., Pittsburgh, Pa.

†Asst. Elec. Engr., The Youngstown Sheet & Tube Co.

whenever they dug in that section of the plant if they hit a plank to stop. One day one of the men did not stop when he hit the plank. The pick went through the plank and sheath of the cable. The man was not injured but steel tapes as applied to parkway cables would have helped to deflect the blow and save the cable.

One of the questions asked here tonight was in regard to relative cost of the duct and ductless type of cable. It seems to me the relative cost is made up of three things: First, cost per duct ft. of laying ducts, which is pretty well established. Power companies will tell us somewhere around 80 cents a foot on ordinary sizes of duct line. In steel plants probably $1.20 is a better figure. As compared with that the armor applied to the same cable runs somewhere between 20 cents and 40 cents a foot. There is an extra amount for hauling in dirt if you need any for slag fill to improve radiation.

One question has come up quite recently in regard to draining of duct lines running through slag or ash fills with tile in order to keep away the concentration of acid from the ducts. That is practical and might be justified and should not add a whole lot to the cost of the job. It means a little extra work and tile will cost about 12 cents a foot.

Another point in the discussion of running cables through fills is that the same type of cable that is used for ductless work is equally adaptable to overhead work. It might be perfectly practical in special cases to come out of the ground, go up on pole line with that cable and go back in again.

R. S. Shoemaker*: I would like to ask Mr. Hood to tell us a little more about splicing. Most of us have a cable system in our plant, low voltage, 2200 to 6600 volts. Soon we will have higher voltage. I think we are interested in what we term high tension cable. Pretty soon we will have 13,200, 33,000. What will be necessary in the way of tools to make splices in 13,200, also 66000? Have we the necessary tools, or will we have to get equipment?

C. F. Hood: On 33,000 volt cable I would certainly say the ordinary steel plant does not have men with the necessary training to make such a joint. It takes highly trained splicers. Every manufacturer will furnish the necessary amount of installation material and filling compound for each joint. These materials are carefully packed and sealed and accompanied with the necessary insulation for applying. Joints can readily be made on cables up to 13,200, and possibly 20,000, but for 27,000 and 33,000 you should get experienced men from utility companies. The ordinary steel plant does not have a personnel sufficiently familiar with it for making these joints. For high voltage cables, there is considerable equipment required, such as machinery for wrapping which does a little better job than hand wrapping. A good deal depends on the men who are wrapping the joint. A man must make certain not to get any moisture on it, not even moisture from his hands. Wearing rubber gloves is one of the precautions taken. Each manufacturer will furnish you a detailed description of how to make the joint and will furnish the men.

H. R. Gravenstreter*: At the present time we are not using any quantity of underground cable. We have it in hand, as Mr. Davenport has mentioned and we will get into it in the near future. The paper has been mighty interesting to me for that reason. Using 250 volt D.C. and not being very familiar with underground work, I am sorry I cannot add anything to what has been said.

*Supt., Maintenance, American Rolling Mill Co., Middletown, Ohio.

*Comb. Eng., A. S. & T. P. Co., Shenango Works, New Castle, Pa.

TWENTY-THIRD ANNUAL CONVENTION
and
IRON AND STEEL EXPOSITION

SYRIA MOSQUE - PITTSBURGH, PA.

June 13th, 14th, 15th, 16th, 17th and 18th, 1927

Syria Mosque, located at Bigelow Boulevard and Lytton Street, Pittsburgh, Pa., has been chosen for headquarters for our Iron and Steel Exposition. Both the auditorium and exposition hall have been reserved for exhibits. Not only have all booths been reserved on the two main floors, but so great has been the demand for space that it was necessary for the committee to use space in the various committee rooms, foyer and all other available locations. There are still some spaces to be had in the committee rooms and foyer. Applications should be addressed to Iron and Steel Exposition, 705 Empire Building, Pittsburgh, Pa.

Webster Hall, two blocks from Syria Mosque, has been selected as official hotel headquarters. This hotel is for men only. For the ladies, reservations may be made at Hotel Schenley which is but two blocks from Webster Hall and Syria Mosque. Make your reservation early.

*Arc Welded Structural Steel Buildings**

By C. G. WATSON†

BY ERECTING a 100 per cent welded steel building The Youngstown Welding Company had no intention of entering the construction business but simply wished to show their confidence in welding and to sell more thoroughly the ideas of welding to the world by proving its possibilities. The building is of standard mill type with monitor 70'x220'. Not a rivet or a bolt was used in the fabrication or erection. Even the derrick used in erection was welded. To those who are interested in the story of the building a brief review of the Youngstown Welding Company and events leading up to it will be important.

The company was started by Mr. Walter D. McKay, the president, in the spring of 1912. Mr. McKay was born in Nova Scotia and came to Ohio when a boy. He served his time as a machinist's apprentice. At the time of starting the welding company he was foreman in his brother's machine shop, now The McKay Machine Company. He started alone the first welding shop between Cleveland and Pittsburgh. Soon after he took in a partner, Martin Rausch, a man with some experience in welding. Mr. Rausch remained until 1919. The business was conducted primarily as a repair shop until 1921. Mr. McKay was quick to grasp the secret of successful welding, "that of taking care of the contraction of welds," and was always ready to pioneer in new fields.

FIG. 1—Control Boxes made of Welded Sheet.

He was successful, and the shop grew to be one of the largest repair welding shops in the country. About 1916 he began welding corrugated steel transformer cases which had formerly been riveted and soldered, and gradually began manufacturing other small tanks. In 1921 Mr. McKay decided to change the business from repairing to manufacturing. With this purpose in view the writer was taken into the business.

At this time many things stood in the way of the successful advancement of the welding industry. It would be hard to list them in order of importance The general belief that welding was primarily a means of repairing and not manufacturing hindered many attempts to use welding in manufacturing. The public thoroughly believed that if an article was broken it could be successfully repaired by means of welding but that it could not be made originally by welding. Along with this was the general lack of information and interest among engineers as to the real facts concerning welding. They were perfectly contented with the former methods used and did not care to bother about changing. The universities of the country barely mentioned welding in the engineering courses. Everywhere precedent stood firmly in the road of any advancements.

There was a lack of interest and a feeling of indifference among those who should have been the most interested. The majority of all steel manufactured is cut into small pieces and then joined together. To my mind there is no better or satisfactory way to do this than by welding or fusing the pieces together. Yet the steel companies to whose interest it should be to produce better and cheaper means of using their product failed to step to the front.

Those manufacturing and selling welding equipment are perhaps one of the greatest drawbacks to the industry today. They insist on selling equipment rather than the ideas of welding which would create a greater demand for equipment. Possibly their own engineers do not believe in welding. We have recently purchased a piece of equipment from one of the very large manufacturers of welding equipment. According to our view, the article could be far easier, better and cheaper made by welding. Yet not a joint was welded and it required twenty-one hours' labor to stop the leaks in the threaded joints before it could be put into service.

FIG. 2—Complete frame of building erected.

There are many other similar instances that could be quoted. I have just inspected a job where the engineer in designing it did not appear to be interested in getting what information was available, or believe that the fundamental principles of engineering and common sense applied to welding. The result will probably be a setback in this line.

One of the most common errors is that the manager of the plant has never employed welding in his

*Presented before Pittsburgh District Section, December 18th, 1926.

†General Manager, Youngstown Welding Co., Youngstown, Ohio.

plant but has been thinking about some piece or part. An equipment salesman calls, he is asked about it and the answer is always "yes." An order for equipment follows, a workman is picked out and sent to a welding school. He comes back, and if there is the slightest chance the job fails, there is a bad taste left in the manager's mouth. Their trouble is not with the

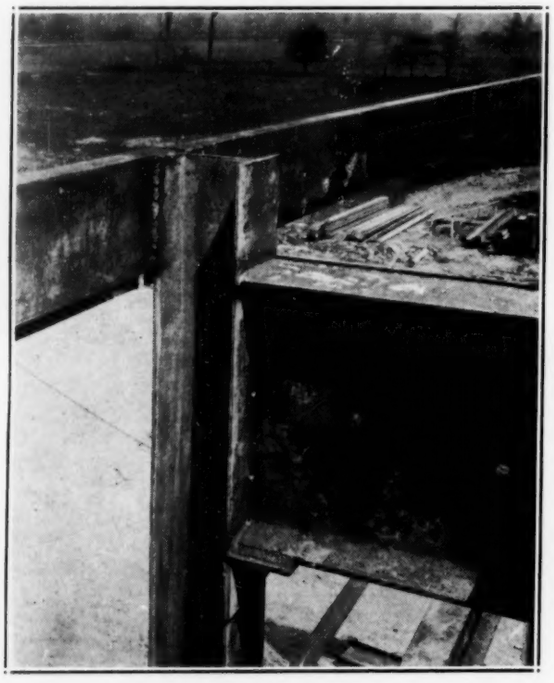


FIG. 3—Method of attaching 24" beams to 8" column.

workman but with the fact that the manager and chief engineer were not taken and thoroughly informed and schooled in the fundamentals of welding before they were allowed to employ it in their work.

Whenever a salesman of welding equipment calls, if you are not too busy, you sit down and listen to

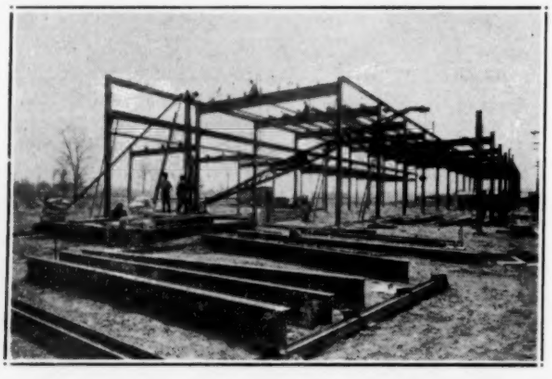


FIG. 4—Frame work of building in process of erection.

a few fairy tales and hear how many railroads have standardized on a certain line of equipment in the past week. The advancement of the welding industry depends upon the selling of the idea of welding and not equipment.

We have used or tried out most all kinds of welding equipment, both oxy-acetylene and electric arc, and have failed to find any material advantage in any particular make. We are still using some of our original torches and our first motor generator set. Far more depends upon the workman than upon the tools he uses.

Failures due to inexperience and improper preparation have been many. Many companies have started in to weld different articles long before they had done the necessary preliminary work to be sure that they were right. War welding stands out as a big example of this, the effect of which is still felt. Along with this comes the lack of skilled and experienced welders which will be overcome in time.

In 1921 when the preliminary work leading up to the building of our plant was started the welding industry was in a state of relapse from the war fever. We were allowed to repair almost anything. Small storage tanks could be welded. They were just beginning to attempt large tanks. Small articles which had formerly been riveted and soldered could be

FIG. 5—Method of erecting building.

welded. New articles that never had been riveted were being designed for and successfully welded. On articles formerly riveted the design could not be changed. When you called on a firm and presented your card with a reference to welding on it, the man at the door or the girl at the information window always came back and politely dismissed you with the information that they had nothing that needed repairing, or that they maintained their own repair gangs.

Our first step into the unknown must be credited to the C. L. Miller Company, of Scottdale, Pa. It was several small orders for coal mining equipment, consisting of shaker screen frames, loading booms, chutes, etc. They were very liberal in that they allowed us to change from the orthodox design formerly used in riveted joints. These jobs were completed with varied success. From an experimental viewpoint the work was a great success, but from a

practical one we are afraid that a part of it at least was a failure. However, this equipment is still in use. Other small experiments followed, then came an order for a bunch of chain troughs for a rolling mill. These were successful both from a service standpoint and from the cost side. We have made many gear guards. Those designed to be riveted and then welded have been consistent failures, but those designed for welding and welded have been uniformally successful. We have also built many structural steel bases for transformers.

The transformer case business has steadily increased. Welded steel cases have replaced cast ones with a saving of weight and cost. Welded truck tanks have been developed and have met with great success. The business of manufacturing oil tight cases and tanks steadily increased until it was necessary for us to obtain larger quarters. There was very little information published on the subject of welded steel

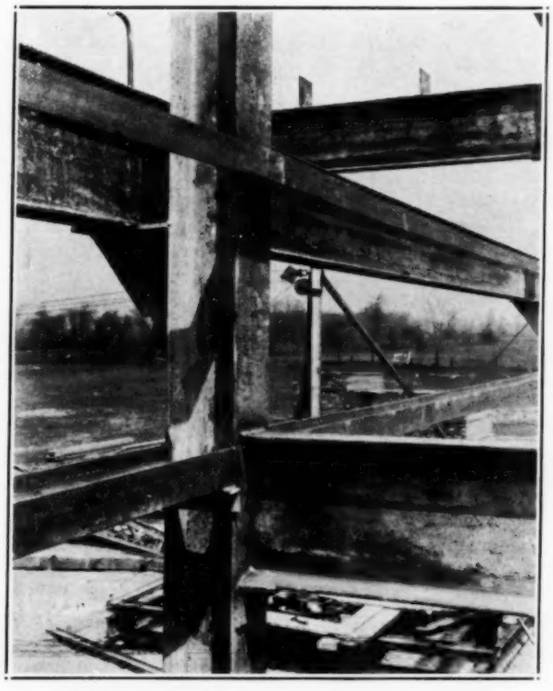


FIG. 6—General method of welded attachments.

buildings, but we were very particular to study carefully all we could get. We kept a watchful eye on all new developments in the industry. The result of our experiments and the information we were able to obtain gave us confidence to go ahead with a welded steel building.

In designing the building we kept in mind the following: First, to design for welding and disregard all precedent in rivet design. Second, to use only standard materials shipped direct from the mill. Standard mill tolerances were to be allowed. The general plan to be followed was similar to that of carpenters framing a building. Third, to design all joints so that they were free to contract without leaving welding strains. All joints that were to be made in the air were to be either vertical or down welds. No overhead welding.

In designing the joints we determined to use only enough welding to give us the required strength for each joint. We took a value of 36,000 pounds per square inch for the average weld. Take for example the joint between the 24″ I beam roof girder and the 8″ H beam column. First, a 6x6x1-2 shelf angle 9″ long was welded to the H. column, by using 20 lineal

FIG. 7—Showing simplicity of attachment of top of crane girders to H column.

inches of 1-2x1-2 weld. This figured at 13,176 pounds per lineal inch gave an ultimate strength of 263,520 pounds or a safe load of 65,880 pounds to hold a direct down pressure of 15,000 pounds (roof load being figured at 50 pounds per square inch.) Next, we used 3 tacks 3″ long on each side of the web, 7″ across the top flange, 3″ on each side of the

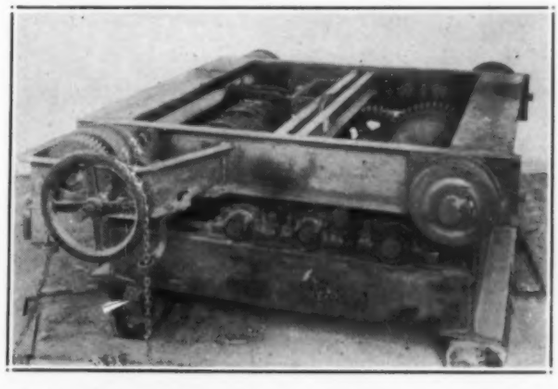


FIG. 8—Complete welded structural steel trolley.

bottom flange, and 6″ along each side of the shelf angle, making a total of 33 lineal inches or an ultimate strength of 434,800 pounds or a safe strength of 108,700 pounds to take care of windage, crane thrusts and etc., giving a combined effective length

of weld of 41″ equal to 540,200 pounds or a safe strength of 135,000 pounds against the limiting value of an equivalent riveted connection of 67,500 pounds.

The main building is 70′x220′ and consists of eleven-20′ bays. The center aisle is 30′ 0″ wide and 25′ 0″ high, with a 20′ 0″ wide by 16′ 0″ high aisle on each side. The ends and curtain walls are brick and tile. The sash is continuous along the sides and monitor. The main columns of the frame work are 8″ 34 pound H′ columns, while the outer columns are 8″-18.4 pound standard I beams. The center roof girders are 24″-79.9 pound standard I beams, with 15″ 42.9 pound used in the 20′ 0″ aisle. Fifteen inch I beams were also bracketed to the H column for crane ways. Ten inch 15.3 pound channels are used as eave struts. Eight inch 18.4 pound I beams are used as compression members between the H columns at the point where the 15″ roof girder connects into the H column. 3x3x3-8″ angles are used

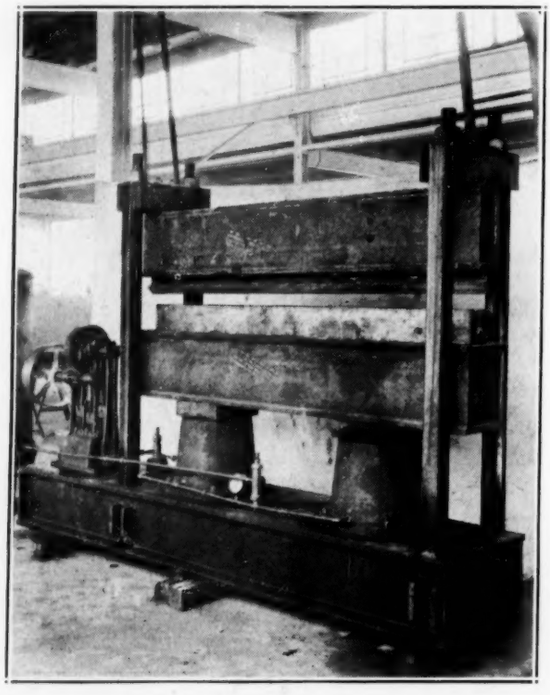


FIG. 9—Welded structural steel applied to hydraulic press.

as lintals and sills for the sash and also for braces and ties. Some 2 1-2x2 1-2x3-8 angles, 4x4x1-2 angles and 6x6x1-2 angles were used as shelf angles. The crane way brackets and column bases were cut from 1-2″ universal plates.

All the steel was ordered to length except shelf angles, etc. Before starting the erecting we checked up the lengths and squared up all of the ends. If a beam was a little short it did not matter, but we were particular not to have any piece too long.

We have found it advantageous to have a little clearance between pieces when starting to weld. The base plates, crane brackets and shelf angles were welded to the columns on the ground. The lintal and eave struts were welded together and the plates for fastening the wood purlins were also welded on before erecting. All holes for nailing strips, etc., were burned and pinned.

In erecting the building we started by setting two end center H columns and then the outer I beam columns. The two 15″ roof girders were then placed in position and securely tacked. Next the second two center columns were set. The compression members were put in. Next the 3x3x3-8 angles underneath the upper sash and then the upper eave strut and sash angles were put on. Next the crane girders were placed. Care was taken to see that the columns were plumb and in place and that the center checked up. Next we placed the 24″ roof girder in the first bay. While we were backing out the derrick and getting more material in place the welders completed the welding of the joints in the first bay. The second set of outer columns were then set and the sash angles and eave struts were put on. Then the second pair of 15″ roof girders and the second 24″ girders were placed, completing the second bay. Then the third set of center columns and so on. Braces and ties were put on last. The girders were placed on the shelf angles and held in place by the derrick until they were securely tacked. The angles, etc, were fastened by C clamps until tacked. The welders were able to keep up fairly well, as they had a chance to catch up while we were moving the derrick and setting columns.

The roofs on the furnace room and the generator house are also a little out of the ordinary in that they were made from number 12 gauge blue annealled sheets 60x144″ and put on much in the same manner as prepared roofing is used. The purlins were placed at 5′ centers with a 1 1-2x1 1-2x3-16″ angle welded between them underneath the seams. The lower row of sheets were first put on and tacked to the purlins and 1 1-2x1 1-2″ angles. The second row of sheets lapped this about 1″. After the entire roof had been laid the welders went back and completed the welding of the seams. This has proved a very satisfactory and economical means of putting on a steel roof.

Seven men made up our erection crew, two welders, four laborers and one pusher. The pusher was the only one who had had any experience in erection and he was formerly a carpenter. Our equipment consisted of two hand wenches on a stiff-legged derrick. This was also welded and assembled on the field. The base being made of 12″ I beams 20′ long in the form of a square, and weighted down with sand bags. When necessary to move it it had to be skidded along greased planks. Our welding equipment consisted of two motor generator sets, an acetylene burning outfit and the necessary chains, ropes, ladders, C clamps, etc. Also a tractor which came in very handy. Each welder was equipped with a lineman's belt, a piece of hose with one end blocked in which to carry electrodes, a rubber holster for his electrode holder and a wire brush. The weather conditions favored us and we were not required to use welding shields, which are very necessary when welding in wind. We were 15 days in erecting the building. However, this does not mean much, as we took two days to complete the first bay and completed the next two bays in one day. To do the same job over we believe we would use three welders, two bridgemen, a ground man and a hoistman, with a power hoist beside the pusher. Time and experience will naturally work out the proper gang for this class of work.

The entire cost of the engineering work, including tracings, blue prints and all did not exceed one hun-

dred dollars. Besides the foundation drawing we made one drawing showing a cross section through the building, one drawing of details and one showing the brick angles, sash and door frames in each end. The drawing of details was unnecessary as they can be sufficiently shown on the cross section drawing. The one showing the end was also unnecessary as the sash drawings gave the same information. Thus for a simple building of the type we built, the one cross section drawing would have been enough. A pencil sketch to the foreman would have done in our case, but at the same time we realize that the amount of drawings will always depend on the amount of information necessary to be given.

The fabrication of the columns and the erection of the building was kept separate. The columns were fabricated for $17.00 per ton, including overhead, while the erection took 840 hours at a cost of $530.00, which represent entire cost of fabrication and erection against an estimate on a similar riveted job of 360 hours at a cost of $540.00 for erection only. There was altogether about 80 tons of steel used in the building. These figures simply show how we came out and have very little value otherwise. On a duplicate job we feel that we could more than cut the time in two, as most of the time the four laborers were employed on the hand hoists. Inexperience also told heavily in running up the time. We are very well satisfied with our attempt and feel that welded steel buildings are the coming thing.

From our experience we believe that many advantages will be gained over the old method of construction.

The engineering work greatly simplified, elaborate and detail drawings will not be required.

The eliminating of the structural shops will be the big item of saving. We found tacking to be as cheap as fitting up bolts and just as satisfactory.

Material may be shipped direct from the mill to the job.

The elimination of the noise of the rivet hammer will be welcomed in the cities.

Freight and handling charges will be largely eliminated. Another advantage will be the saving of material and the simplifying of certain difficult connections. For instance the brace angles and ties can simply be welded across the face of the columns and beams without any clip angles or other connections. A good example is the manner in which we connected the top of the crane girders to the H columns. We took a piece of 6x1-2″ bar about 5″ long and held it up under the upper flange of the 15″ beam and tacked it to the H column. It was then welded on to the H column and to the I beam, thus tying the beam to the column. In a similar riveted connection the webs would have been fastened to the H beam by means of four clip angles and a gusset plate requiring the punching of 30 holes and the driving of 18 rivets. In case of errors the material is not wasted and the error can easily be corrected. We had an example of this in that by some error in measurements in part of our main columns, the crane brackets were welded on 5″ out of place. All that was necessary to correct this was to take a torch, cut the bracket off and reweld it to the column in the proper place. This was accomplished in a very short time and without leaving any perceptible trace of the error. We were greatly impressed with the flexibility of the entire job. Changes as a rule can easily be made without any loss of time or material.

After we started the job we changed the size of the sash and the entire arrangement of doors and other openings in the two ends of the building without any loss of material or time. An exact fit in the joints of the beam are entirely unnecessary as the welding fills up any discrepancies of measurements. As careful as we were to check the building as we went along in one place we found a column apparently plumb in all directions, yet it was necessary to cut half an inch from the compression member on one side, which was done with a gas torch and to add half an inch on the other side, in order to come out right.

The necessary field equipment required is light and inexpensive. The entire cost of the equipment used on our job did not exceed $3,000.00.

The movement has barely started at the present time. Much remains to be done in the way of design and development of skilled welders who can climb and the education of the general public to the possibilities of welding.

DISCUSSION

W. L. Warner*: Mr. Watson's paper contains much information of interest not only to the structural steel industry but also to the welding industry. Much has appeared in the public press during the past four years relative to the erection of steel structures by welding. Some of this information has been and is still of great value while a part of it has been of the nature of enthusiastic outbursts by proponents or opponents of the process.

This building described by Mr. Watson which was built by the Youngstown Welding Company is of great importance from the welding standpoint in that it was designed for welding by a welding company and built by that same company. Welding was an essential factor in the design and construction. In this instance there was no precedent or set procedure to hamper either the designer or erector and it is therefore reasonable to suppose that welding would show up to good advantage, which it did.

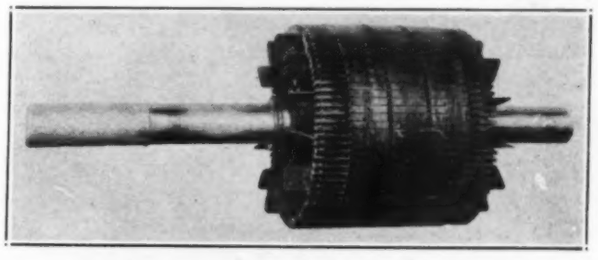


FIG. 1.—Armature Shaft Built up by Automatic Arc Welding Machine.

I believe that the information given by Wr. Watson shows an advantage in eliminating erection bolts. Just what the limitations are in this respect Mr. Watson's paper does not show but the one big thing is that the traditions of riveting were disregarded in the erection and that item certainly is worthy of consideration. One serious obstruction to the advancement of any new process is the inability of the users to relinquish the traditions of the older

*Industrial Engineering Dept., General Electric Co.

process. Various analogies might be given to prove the point but that is not essential.

The question of cost is also of significance here. Mr. Watson shows that the total cost of fabrication and erection of this building is about equal to the erection cost of an equivalent riveted building. Here

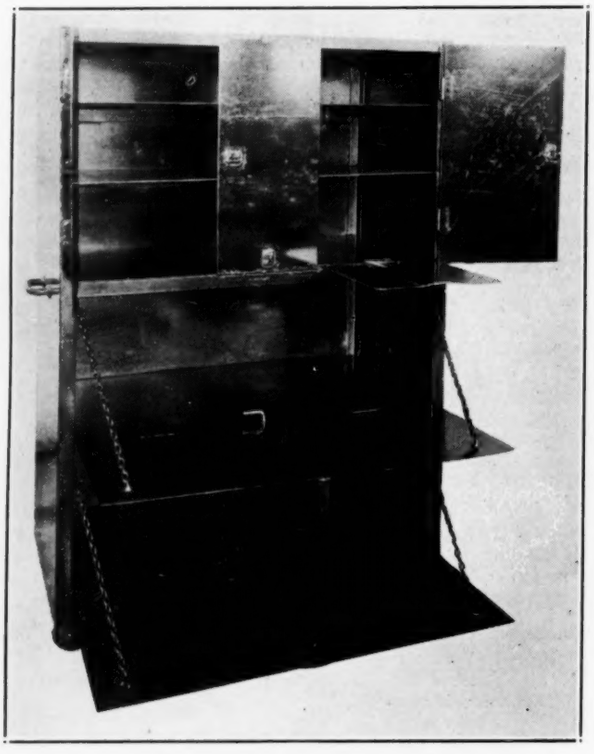


FIG. 2.—Electric Arc Welded Steel Shop Cabinet.

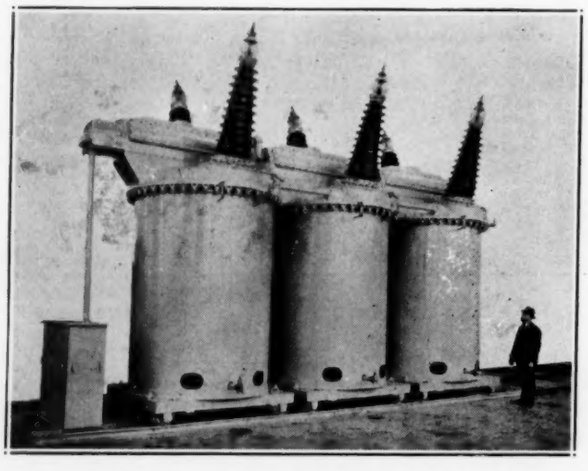


FIG. 3.—Three Phase Bank of 220,000 volt oil circuit breaker with welded tanks.

again is an instance where the situation allowed of taking advantage of opportunities afforded to the fullest extent without being hampered by precedent. No fabricating shop was needed as all of the material was prepared for erection at the site. No exception was made to the standard rolling mill tolerances and this feature also is worthy of note.

The flexibility of construction afforded by the welding process is strikingly brought out in this paper by the instances mentioned by Mr. Watson. In the case of the error of locating the crane brackets the connection would have been considerably more costly with rivets and more time would undoubtedly have been required for the change.

Regarding the connection of the 24" I roof girder to the 8" column, as the joint is actually made, the factor of safety is approximately 8 or 2 times greater than necessary. We believe that a weld on each end of the vertical leg of the 6x6x½ seat angle

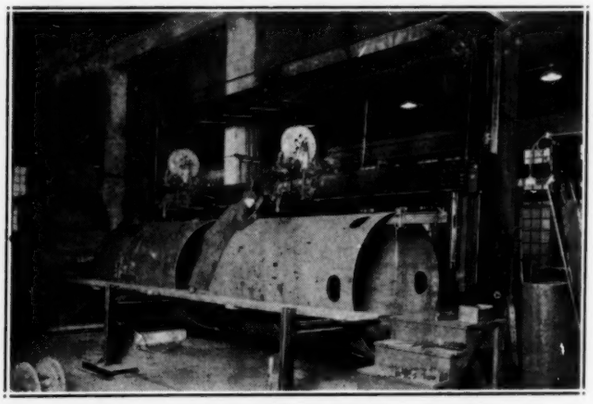


FIG. 4.—Welding Oil Circuit Breaker and Oil Switch Tanks with Automatic Arc Welding Machine.

to the column face would be quite satisfactory. This would give a weld 12 inches in length capable of carrying a load of almost 40,000 lb. of shear. The actual shearing load is 15,000 lb. as is stated by Mr. Watson. We also believe that a ½x½ inch weld across the top flange of the 24 inch I beam and a ½x½ inch weld along each side of the lower flange across the outstanding leg of the seat angle would provide sufficent strength for the connection of the I beam to the column. This would provide a

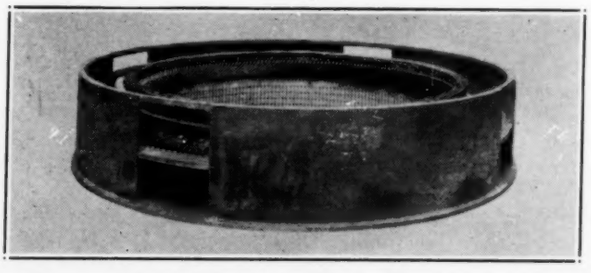


FIG. 5.—Arc Welded Steel Stator Frame for Water Wheel Generator.

total of 19 inches of weld between the I beam and column. The safe strength of this weld would be, therefore, 62,700 lbs., probably ample for the load to be carried. The advantage of cutting down on the amount of weld would be to speed up the erection and reduce costs. If additional welding is required then a weld can be easily made on the web of the beam.

The welding profession cannot help being enthused over the work done on this building and also the building now under construction at Sharon, Pa., by the American Bridge Company. The two

buildings are of different types and entirely different methods are used in the designing and erecting. Criticisms will be offered and, of course, it is natural that this should be so. Nothing new or of a pioneering nature has ever been attempted without criticism. We learned by experience and after all has been said and done it must be admitted that welding has

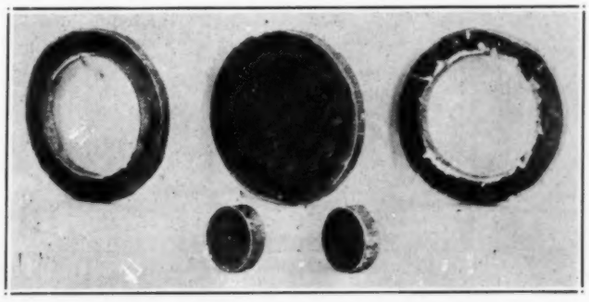


FIG. 6.—Rolled Steel Parts for Welded Gear Wheel.

made a notable start in the field of building construction.

Mr. Watson made a certain statement regarding the manufacturers and sellers of welding equipment being one of the greatest drawbacks to the welding industry today. I cannot conscientiously let that statement pass without making some comment in support of the apparatus manufacturers, especially the General Electric Company, although Mr. Watson may be assured that the criticism is taken in the

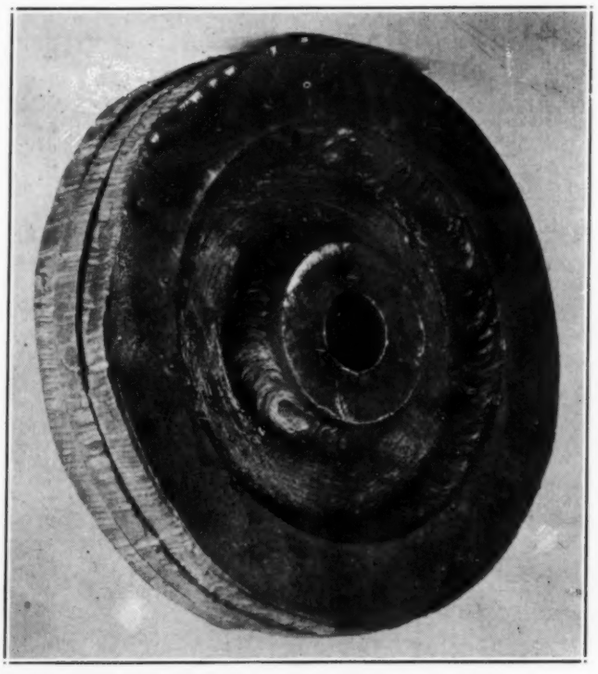


FIG. 7.—Gear Blank of Rolled Steel Plate put together by Welding.

friendly spirit in which it was given. I wish to show you briefly some of the uses the General Electric Company is making of welding.

Fig. 1 shows a repair job building up worn motor armature shafts by automatic welding.

Fig. 2 shows all arc welded steel cabinet. Several hundred of these of different sizes have been built. Also shop stools, chairs, small trucks, wheelbarrows, and shop tables.

Fig. 3 shows bank of 220,000 volt oil circuit breakers with welded tanks. Tanks about 12 ft. high and 8 ft. diameter, Longitudinal seam a butt strap.

Fig. 4 double arc automatic welding oil circuit breaker tanks. Between 5,000 and 10,000 oil switch

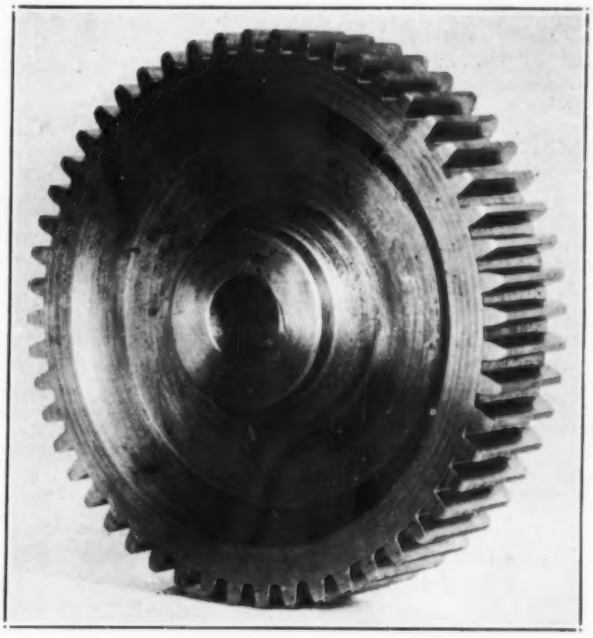


FIG. 8.—Completed Gear of Rolled Steel Plate.

tanks from 12" in diameter up to 114" in diameter are constructed per year. This figure does not include transformer tanks.

Fig. 5 Welded stator frame replacing cast frame.

The next three photos show a new method of making gears that stand the banging of all kinds of service.

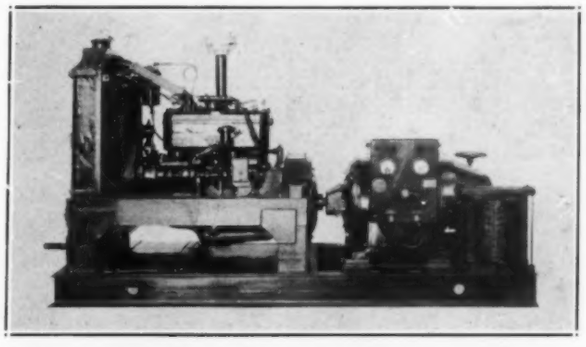


FIG. 9.—Arc Welded Structural Steel base for Motor Generator Set.

Fig. 6 shows the various parts used. These are of rolled steel plate.

Fig. 7 shows the parts welded together with the automatic arc welder with hole cut for the shaft.

Fig. 8 shows the completed gear.

Fig. 9 shows a gas engine set with welded structural steel base.

These are a few of the things the General Electric Company is doing in the way of using welding. There are many others which we haven't time to discuss. In regard to structural welding the Company has used welding in several instances and is still using it in a small way. Our designing engineers have been and still are studying the problem from the standpoint of desirable information with a view to determining safe strengths of various sizes and lengths of weld for design purposes.

A. M. Candy: Within recent years there has probably been no development of more vital interest to the steel workers and building industry at large, than the series of tests recently conducted at Carnegie Institute of Technology in Pittsburgh, Pa., by the Westinghouse Electric and Manufacturing Company. These tests proved so conclusively that properly designed and fabricated arc welded connections have so many merits that a contract was awarded

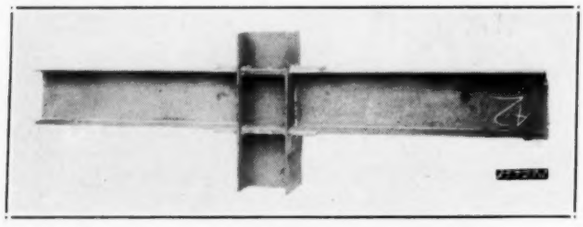


FIG. 1.

to the American Bridge Co. to construct a five-story 70'x220' mill type building 80' high at the Sharon Works of the Westinghouse Electric and Manufacturing Co.

We believe that the data on these tests will be desired by the engineering and welding world in advance of the complete data on this building. The complete series of tests included a total of 22 specimens typifying various structural joints and members which would most conclusively prove the merits of the process to engineers who have not had an opportunity to make a study of this work. Space

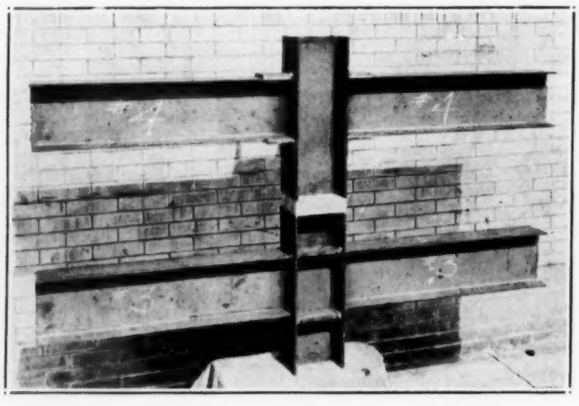


FIG. 2.

limitations will not permit an exhaustive study of all the specimens and therefore we will only give details of the most interesting specimens.

The design of column connections offers a very interesting study in that continuity may be obtained with arc welding at much less expense than where riveted designs are used. Furthermore, the welded connections are stronger than the conventional riveted connections.

To substantiate these ideas a series of three test specimens were built as illustrated by Fig. 1 and 2. Each specimen comprises an H column eight inches deep, two feet high, weighing 32 pounds per foot and two cantilever Bethlehem I beams nine inches deep,

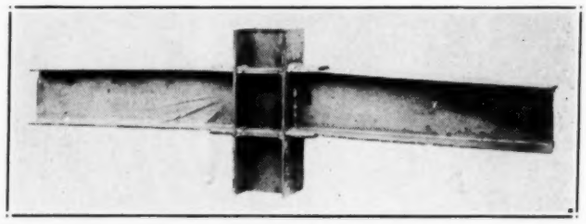


FIG. 3.

three feet long weighing 20.5 pounds per foot. The detail connections for the specimen are as follows:

Specimen No. 2 was constructed by welding two seat angles 4"x3"x⅜"x6½" long, across the faces of the column with the 4" legs outstanding. Only the ends of the 3" legs were welded to the column with a 5/16" bead. This welding was done in a downward direction by turning the column to typify shop fabrication. Four continuity plates each 3"x5/8"x 6 5/8" long were then located against the web of the column between flanges so as to be directly in line with the flanges of the cantilever beams. The column was turned to permit all downward welding the same as for the seat angles. These continuity plates were heavily welded with a ⅜" fillet entirely around their ends against the column flanges. The column was then placed on end and the I beams were landed on the seat angles with approximately a 3/16" opening between the beam ends and the column faces. The entire ends of the beams were

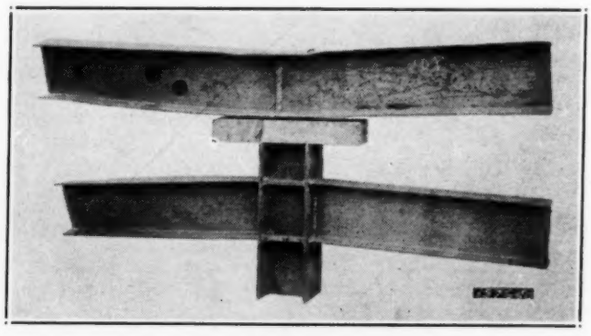


FIG. 4.

then welded to the column faces. Also the edges of the beams were welded four inches along the line of the outstanding legs of the seat angles. Two top reinforcing plates each 4"x½"x4½" were then located on top of the beams with the 4" lengths adjacent to the column faces. These ends were welded to the column faces and the 4½" lengths were welded to the top flange of the beams.

Specimen No. 3 differed from No. 2 in that no seat angles and no reenforcing plates were used.

Specimen No. 4 differed from No. 2 in the very vital item of omitting the "continuity plates" from the column flanges.

Each of these specimens was turned upside down and mounted on rocker blocks 5" wide located with their centers 3" from the beam ends, thereby providing a span of approximately 6'2½", the load being applied on the upstanding end of the column.

The results of the tests are shown by Fig. 3 for No. 2, Fig. 4 for No. 3 and Fig. 5 for No. 4. Fig. 6

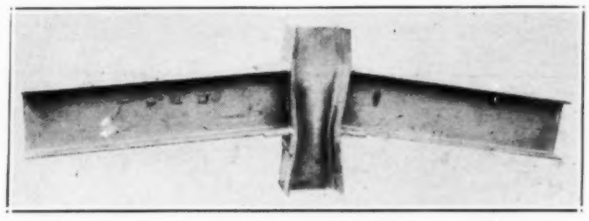


FIG. 5.

shows the stress diagrams of the three specimens to permit of direct comparison. The following table gives the pertinent data:

Specimen No.	Pouds Elastic Limit	Pounds Ultimate Load	Bending Moment at Column Face in Inch Pounds	Remarks on Ultimate Load
2	57,000	70,000	1,165,000	No. 2—31% higher than No. 4
3	50,000	68,550	1,130,000	No. 3—28% higher than No. 4
4	28,000	53,400	878,000	No. 2— 2% higher than No. 3

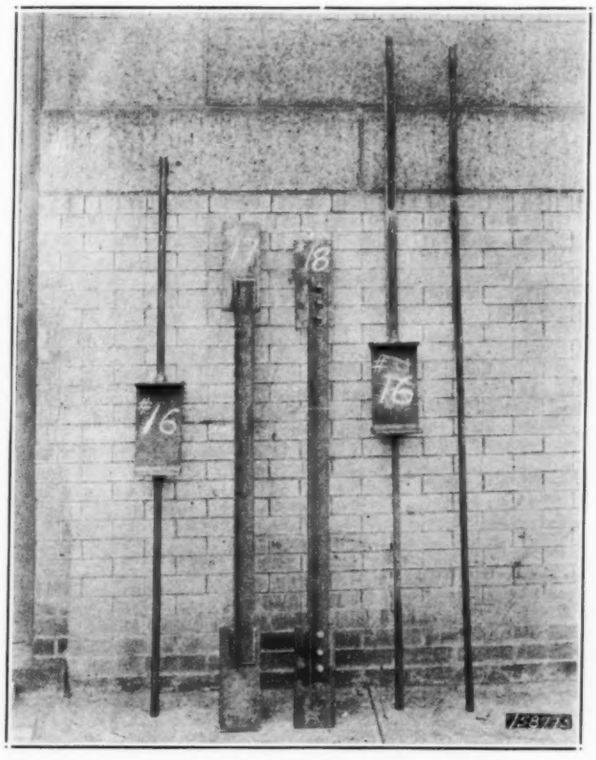


FIG. 7.

It is interesting to observe that none of the specimens had a single failure in the welds. Specimens No. 2 and No. 3 failed by web crippling of the cantilever beams and No. 4 by web buckling of the column. The fact that No. 2 shows 2 per cent greater ultimate capacity than No. 3 is attributed to the stiffening effect both in the vertical and horizontal planes produced by the top reenforcing plates and the outstanding legs of the seat angles. The very marked difference between No. 2 and No. 4 is, of course, due to the "continuity plates" in the column of No. 2 which produce an effect identical with that of having the two cantilever beams carried continuously through the column. This construction is

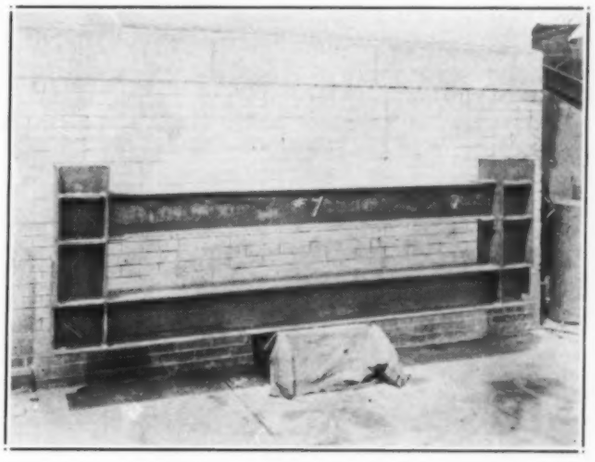


FIG. 9.

carried out completely through the Westinghouse Sharon building.

To show the advantages gained by simply substituting arc welding for riveting in tension members, two specimens were prepared as shown by No. 17 and No. 18 in Fig. 7. Specimen No. 17 comprises two angles 2½"x2"x3/16"x4' long with their 2½" legs located against two shank plates ¾"x5"x1" long with the angles over-lapping the plate ends 4". The heel and toe of each angle was welded along the 4" length and across the ends of each angle to the

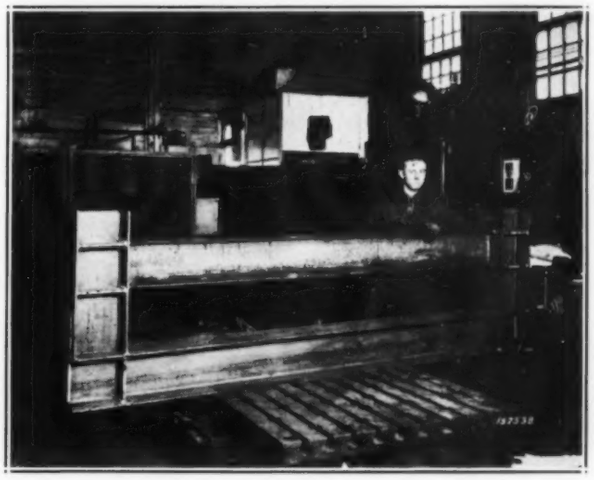


FIG. 10.

shank plates. Specimen No. 18 differed slightly in that the angles were 4'2½" long, over-lapped the shank plates by 6½" and were riveted to the shank plates with six rivets ⅝" diameter, power driven in 11/16" diameter holes.

The comparative failures of these specimens are shown by Fig. 8. The welded specimen failed

through the 2½" leg first, followed by tearing through the 2" leg adjacent to the end of the shank plates. The riveted specimen failed through the first rivet hole at the end of the shank plate.

The following table gives the pertinent data:

Specimen No.	Pounds Elastic Limit	Pounds Ultimate Load	Uitimate load in pounds per sq. in. of sectional area of the two angles
17	70,000	94,000	58,000
18	60,000	72,000	44,500

In addition to the fact that the welded specimen was more than 30 per cent stronger than the riveted specimen it is interesting to note in passing that

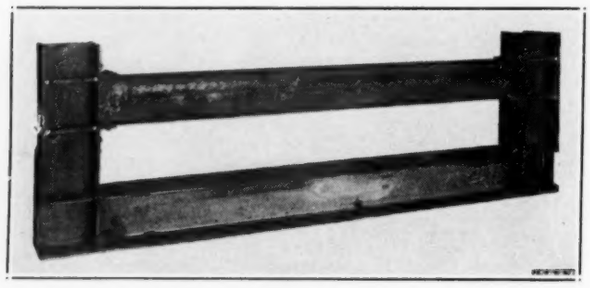


FIG. 11.

the elongation of the welded specimen was 168 per cent greater than the riveted specimen, the values being 1.12" between lague points 4'3½" apart for the riveted specimen and 3" for the welded specimen measured over a length of 40".

A series of three simple beam specimens were constructed as per Figs. 9, 10 and 11. For each of the three specimens identical super-structures to support the beams were constructed by arc welding using 10" H sections weighing 49.5 pounds per foot,

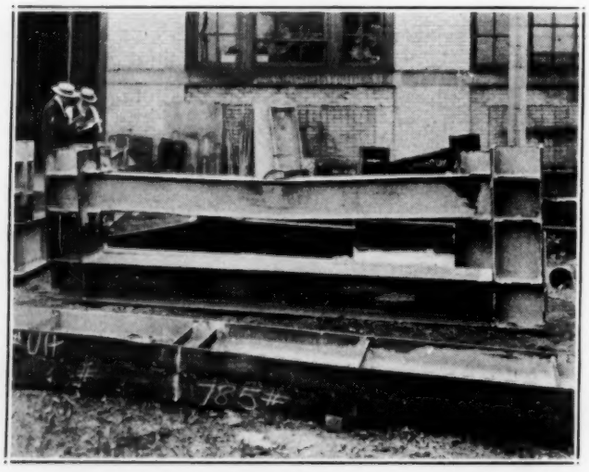


FIG. 12.

the base section being 9'1¾" long and the column sections being 2'3" high. The "continuity plates" were ⅝"x4"x8¼" long. The back stress plates tying the column faces to the base web were ½"x6"x1'4" long. The beam member of each specimen was a 9" I weighing 21.8 pounds per foot, 7'11⅜" long.

In the case of specimen No. 7 two seat angles 3"x1"x⅜"—5" long were welded along the ends of the 3" leg to the columns. The structure was then turned in the upright position and the beam was landed in position on these seat angles. The beam ends were then welded to the column faces and landing angle; also reenforcing top plates 4"x7/16"x5" long were added and welded exactly as described for specimen No. 2.

Specimen No. 8, Fig. 10 differs only from No. 7 by the omission of the seat angles and top reenforcing plates for the beam to column connections.

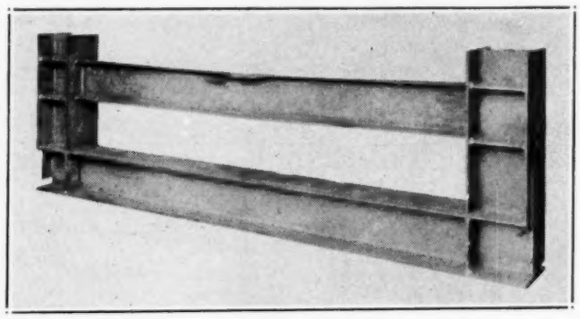


FIG. 13.

Specimen No. 9, Fig. 11 is materially different in that the beam to column connections follow standard riveted practice. Two top and bottom angles ½" thick and a total of twenty rivets ¾" in diameter, power driven in 13/16" diameter holes were used.

Each of the specimens was centrally loaded on a block 1½"x5"x8" long placed with the 8" dimension across the top flange of the beam. In each of the three specimens failure took place by web crippling and flange buckling, at the center of the beam as per Figs. 12, 13 and 14. It is interesting to note however, that in the case of the riveted specimen

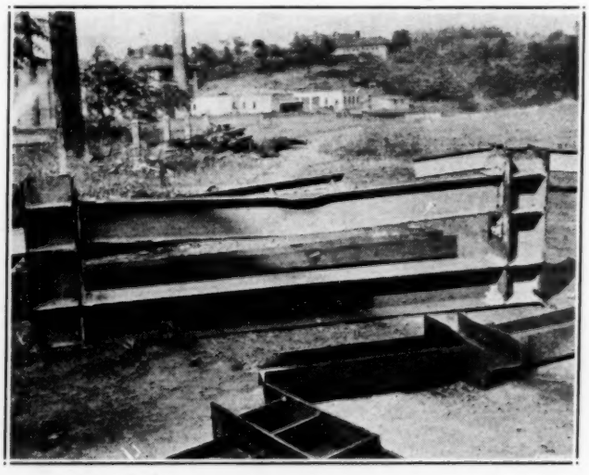


FIG. 14.

No. 9, although the major failure was web crippling at the center of the beam, a preliminary failure by bending of the top angles produced a V shaped opening between the beam end and column faces as illustrated at left end of beam in Fig. 14. This preliminary failure of the top angles was responsible for the early ultimate failure of the specimen as shown by Fig. 15 and the following table:

Specimen No.	Pounds Elastic Limit	Ultimate Load	Remarks on Ultimate Load
7	50,000	73,500	#7—25% higher than #9
8	50,000	67,200	#8—14% higher than #9
9	42,000	58,700	#7— 9% higher than #8

As in the case of specimen No. 2 and No. 3 we attribute the superiority of No. 7 over No. 8 to the stiffening effect, in both vertical and horizontal planes, produced by the top reenforcing plates and the outstanding legs of the seat angles.

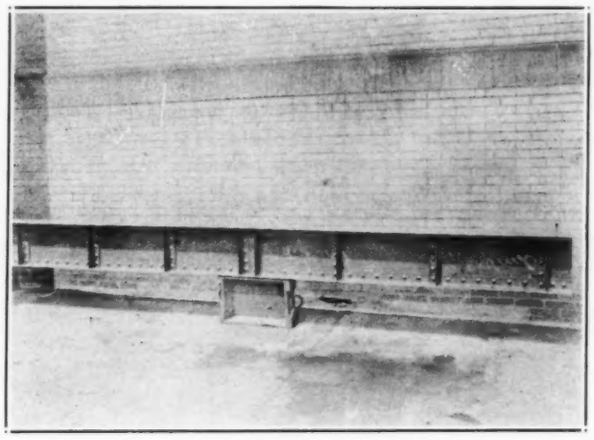


FIG. 16.

In the case of specimen No. 7 the sum of the positive and negative bending moments was 1,760,000 inch pounds. As the welds showed no distress and as the columns did not perceptibly deflect, the negative moment at either end must have been nearly as great as the positive moment at mid-span. For purposes of comparison with tests 8 and 9; assume this test a case of perfect fixed ends, positive and negative moments being each 880,000 inch pounds. This corresponds to maximum fibre stress of 46,500 lbs. per square inch.

For specimen No. 8 the sum of the positive and negative bending moments was 1,618,000 inch pounds. Assuming same ultimate positive bending moments as in test No. 7, the negative moment at column face would be 738,000 inch pounds, indicating 84 per cent fixation.

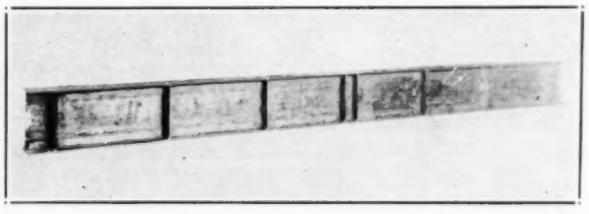


FIG. 17.

For specimen No. 9 the sum of positive and negative bending moments was 1,410,000 inch pounds. Assuming same ultimate positive bending moment as in test No. 7, negative moment would be 530,000 inch pounds, indicating 60 per cent fixation. Such a degree of fixation could not have been obtained with an ordinary type angle 5/16″ or 3/8″ thick.

There is probably no more fertile field for the use of arc welding than that afforded by built-up members, such as girders, columns, etc., which exceed the sizes of existing rolled shapes. For this reason it was decided to build up a series of four specimen girders as illustrated by Figs. 16, 17, 18 and 19.

The riveted specimen No. 20 comprises a web plate 5/16″x14″x15′0″; four flange angles 3″x4″x 5/16″; sixteen web stiffener angles 2½″x3″x¼″ and filler plates. A total of 116 rivets ¾″ diameter power driven in 13/16″ diameter holes were used to fabricate the girder.

Specimen No. 19, Fig. 17 was constructed of the same parts but assembled by arc welding. The top flange angles were welded to the web plate by

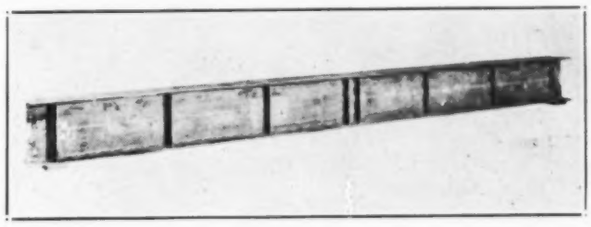


FIG. 18.

intermittent welds 1 in. long on 3 in. centers along the toe of both the top angles. The backs of the angles were welded together and to the edge of the flange plates intermittently using 2 in. long welds on 3 in. centers. At each end the angles were welded solid to the web plate at both the heel and toe for a distance of 3 in. The bottom flange angles were welded to the web plate solid for a distance of 6″ at each end of the toe, the remainder of the weld along the toe of the angle being 2 in. on 5 in. centers. The heels of these angles were welded solid and also to the edge of the web plate for a distance of 6 in. The remaining portion of this same joint was intermittently welded 2 in. on 5 in. centers. The filler plates were welded to the web plate by means of 2 in. long welds at the neutral axis and ½ in. welds at the ends of the filler plates along the web plate. The stiffener angles were completely welded around the entire periphery making contact with the flange angles, and also 2 in. welds at the heel and toe of these angles exactly in line with the 2 in. welds made at the edge of the filler plates to the web plate, the completed specimen weighed

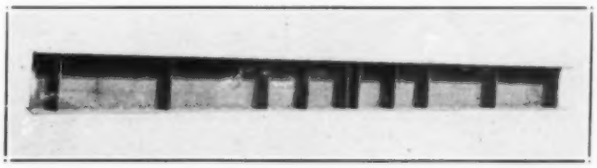


FIG. 19.

785 pounds. The amount of welding wire required to complete the specimen was 27 pounds 8 ounces. The total time to complete the specimen was 14 hours and 10 minutes.

Specimen No. 21, Fig. 18 was designed strictly to take all advantage of the possibilities of joining structural steel members by the use of arc welding to produce a girder of equal strength using less weight of steel. In this respect it is entirely dif-

ferent from No. 19, which is simply a riveted design welded.

The specimen comprises a web plate 14″x5/16″x15 ft. long; two flange plates, 10″x⅜″x15 ft. long; and 16 web stiffener plates 3″x¼″x1′1¾″ long. The top flange was welded to the web plate continuously along each side of the web plate. The bottom flange

FIG. 20.

was welded to the web plate solid for a distance of 6 in. from each end and then intermittent welds 2 in. long on 4 in. centers the rest of the distance on each side of the web plate. The web stiffeners were welded solid to the flanges around the entire periphery at each end of each web stiffener. Each web stiffener was also welded 2 in. on each side at the neutral axis and at intermediate points 1 in. long at each side of each stiffener half way between the neutral axis and the flanges of the girder. This

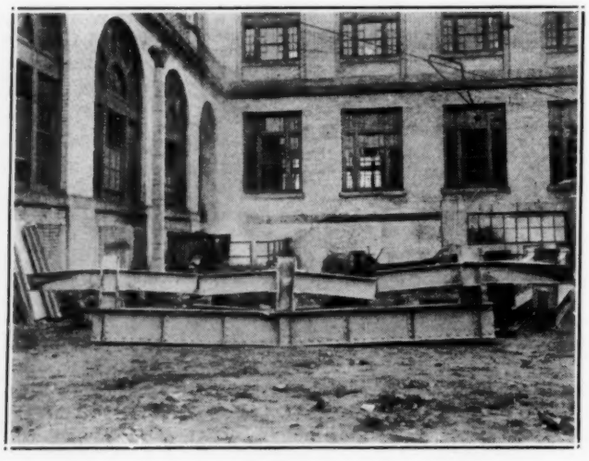


FIG. 21.

specimen had a total finished weight of 656 pounds which is 18 per cent less than that of the riveted girder No. 20, which weighed 798 pounds; and 16 per cent less than (the riveted design welded) specimen No. 19 which weighed 785 pounds.

Specimen No. 21-A, Fig. 19 was also designed to take all possible advantage of arc welding and to use an amount of steel having about the same weight as the riveted girder No. 20. It is similar to No. 21 except that the web stiffening plates are 4½″x¼″x1 ft. 2 in. long, there being a total of 20 used and a top reinforcing plate 9″x5/16″x6 ft. long was welded to the top flange. This plate was welded solid across each end and solid along each edge from the center of the girder to a point 1 ft. 2 in. from the center of the girder. The remaining length of the edge of the plate was welded intermittently 2 in. welds on 4 in. centers. This girder had a completed weight of 795 pounds, and required 30 pounds, 12 ounces of welding wire to complete the welding work. The total welding time was 16 hours and 50 minutes.

All of these girders failed in a very similar manner, namely principally by buckling of the top flange as per Fig. 20 for No. 21 and No. 19; Fig. 21 for No. 20; and Fig. 22 for No. 21-A.

The graphical comparison of the girders is shown by curve 141234 on which appears the tests for the two duplicate riveted girders No. 20 and No. 20-A. In the following table the pertinent data is given

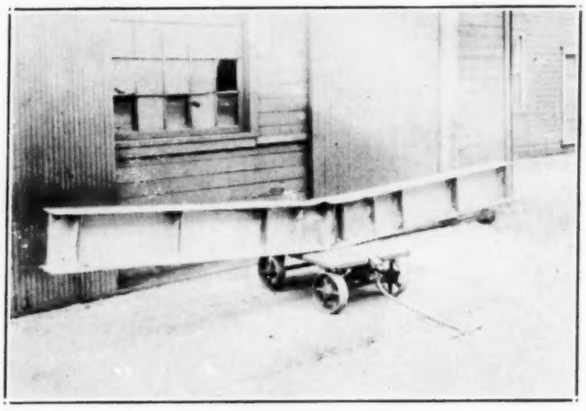


FIG. 22.

in which the data given for the specimen No. 20-B is the average of the data for the two specimens No. 20 and No. 20-A:

Specimen No.	Pounds Weight	Pounds Elastic Limit	Ultimate Load	Max. Bending Moment, Ft. Lbs.	Maximum Fiber Stress Lbs. per sq. in.
19	785	65,000	77,200	270,000	53,800
20-B	798	57,500	71,450	250,000	49,200
21	656	65,000	78,000	273,000	52,700
21-A	795	60,000	110,360	386,000	

COMPARATIVE DATA

Weight	Ultimate Load
#21-A ½% below #20-B	#21-A is 59% above #20-B
#21 is 18% below #20-B	#21 is 9% above #20-B
#19 is 1½% below #20-B	#19 is 8% above #20-B
#21 is 16½% below #19	#21 is 1% above #19

A few deductions of interest may be drawn from these girders, for example, since No. 19 and No. 20 are made up from duplicate parts one should be as strong as the other. We find, however, that although No. 19 is slightly lighter it developed 8 per cent greater strength. This is attributed to the fact that welded connections are much more rigid than riveted connections, but the feature of even greater importance is the fact that the heels of the flange

angles were welded together and to the edges of the web plate, which makes the two sets of flange angles practically the equivalent of a solid plate, therefore, materially stiffening these members as compared with the riveted construction.

During the tests of these girders none of the welds showed any signs of distress even at the points of maximum stress. Fig. 23 is a close up of No. 21 taken of the weld joining the web and top flange at the point of maximum buckling. Similarly Fig. 24 shows specimen No. 19 and Fig. 25 shows specimen No. 21-A.

All of the above girders were tested by central loading on a bearing plate 1½"x5"x8" long placed lengthwise across the top flange of the beam.

SUMMARY

By perusal of the data which is given in this article it is manifest that the tests fully demonstrate the following facts:

(1) Welded joints can be constructed in such manner as to develop fully the ultimate strength of the structural members connected.

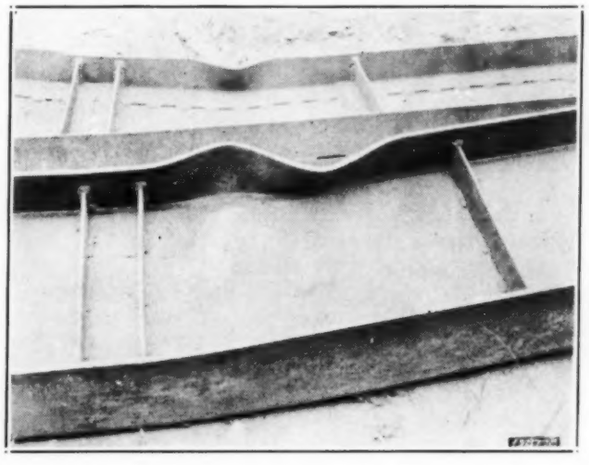


FIG. 23.

(2) Beams and girders can be connected to columns so as to produce absolute fixation.

(3) Lines of beams or girders can be connected so as to provide complete continuity across the supports, whether the supports be girders or columns.

(4) That a steel I beam of given sectional length will sustain a far greater load if fixed at its ends by a suitably designed welded joint than if supported by standard riveted connections consisting of top and bottom angles. A 9 in. standard I beam framed between rigid upright columns 8 feet apart by means of specially designed welded connections sustained a load 25 per cent greater than a beam of the same size and length framed between columns by means of riveted top and bottom angles of ½ in. thickness.

(5) A plate girder assembled by welding and consisting of nothing but sheared plates, has a far greater bending strength than a riveted plate-and-angle girder of the same weight, due to the better distribution of the steel in the cross section. A 15 in. plate girder assembled by welding and simply supported on a 14 ft. span developed more than 50 per cent greater strength than a riveted plate-and-angle girder of the same depth and the same weight.

(6) A double angle tension member such as is used in trusses was connected at the ends by welding and when tested to tension failure broke through the angles at a load 30 per cent greater than the load at which a hanger consisting of the same size angles with riveted end connections failed.

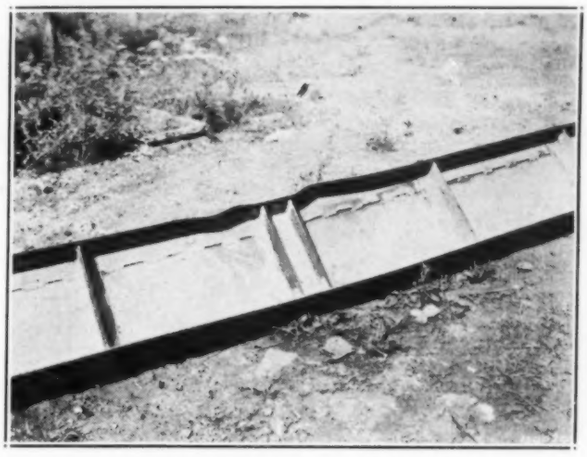


FIG. 24.

The prevailing impression among the witnesses was that these tests demonstrated the superiority of welded connections to riveted connections in every case where direct comparisons were made, and brought out two general facts:

(1) That complete continuity of lines of beams can be obtained in welded construction, whereas it is well known that this cannot be done in riveted construction.

(2) That in a welded building it will be possible to make every joint develop full strength of the main members, whereas in a riveted building many joints are weaker than the members due to the weakening effects of the rivet holes and the weakness of steel angles which have to be used for transmitting tension between two members at right angles to each other.

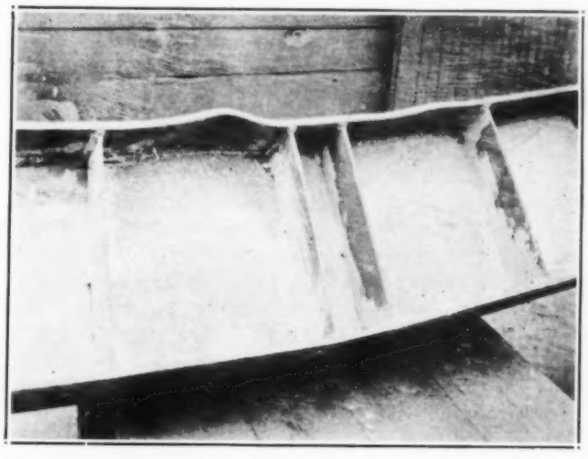


FIG. 25

It was proved that a welded plate girder was 50 per cent stronger than the riveted girder of relative depth, length and weight.

The tests proved the entire practicability of welding without any misgivings as to safety.

The joints that were demonstrated here are being used in the five-story steel building 70x220 ft., 80 ft. high, now being fabricated and erected by the American Bridge Co. for the Sharon Works of the Westinghouse Electric and Manufacturing Co. The typical beam and girder connections are fully continuous connections thereby permitting large percentage (about 12 per cent) of saving in the weight of the beams and girders to carry a given load. The same type of connection which develops continuity also effectively stiffens the building against wind. The equivalent cannot be obtained by any known riveted joint.

CREDITORY

The design of the test specimens described above, and the design for the welded steel building for the Westinghouse Electric and Manufacturing Co. at Sharon, Pa., were produced by Mr. Gilbert D. Fish, Consulting Structural Steel Engineer, co-operating with the arc welding engineers of the Westinghouse Company.

All material for these test specimens was furnished gratis by the American Bridge Co., and was specially prepared under the direction of Mr. Marshall Williams, Assistant to President of that Company. Complete data upon the physical properties of all of this steel, including tensile tests and chemical analyses were also supplied, and great care was taken in selecting the steel material so that in so far as possible, it would be from the same heat so as to secure uniformity in comparing the various specimens.

All of the testing work was carried on at the Carnegie Institute of Technology on an Olsen machine of 400,000 lb. capacity by Mr. J. M. Daniels, instructor in charge of the Materials Testing Laboratory, and his assistant, Mr. Arthur Haeppel. The actual welding of the specimens and all records of tests were carried out under the direction of Mr. A. M. Candy, Welding Engineer, and Mr. C. T. Eakin of the Material and Process Engineering Department of the Westinghouse Company.

The Westinghouse Electric and Manufacturing Co. hereby desires to record acknowledgment of the service rendered in this work by all of the above mentioned parties and assistants working under them.

D. M. Petty: In listening to this very interesting paper, it occurs to me that possibly some of the difficulties of holding a member in place when it is landed could be overcome if a few punched holes were provided at convenient places in those pieces that come from the mill cut to length. The regulation drift pin could then be used in getting the various pieces placed and a bolt or two put in to hold until the welder reached that point. In some cases this would undoubtly speed up the job and enable the welder to work more efficiently.

It is true that arc welding has been considered primarily as a repair operation and now that the author and his partner as well as others have started the use of arc welding as a manufacturing operation we will doubtless see more rapid development in the uses for arc welding.

At this time however it might be well to point out that before arc welding can replace rivets in all building operations it will be necessary to revise a number of our present building laws. I believe there will be no difficulty in doing this once reliable methods to be used in buildings are worked out, tested and standardized.

While the problem is being solved however there are many places in all buildings where arc welding can to great advantage replace rivets, such as, stair railings, braces, window frames and the like.

From a beginning on these things the use of welding will undoubtly grow with now and then a completely welded building until arc welding finally will make its place in the structural building field.

At present one of the greatest advantages is the ability of the builder to order a few standard beams, angles and channels taken to the sight of the building, go there with a welder and a cutting torch and build a building just as the carpenter now does with lumber. When this fact becomes generally known we will see many steel buildings replace frame buildings and thus we, the Electrical Engineers, will again assist our own plants by creating a new market for steel.

Discussion presented before Philadelphia Section on Paper by A. G. Bissell, on "Arc Welded Structural Steel Buildings"

George H. Schaeffer*: I have enjoyed Mr. Bissell's paper very much. It seems to have opened a new line of welding in structural steel. Our plant problems do not seem to fit into this paper, in that our welding seems to be of an entirely different nature. At our plant we often have to add a lot of metal, and we are at a loss sometimes to know whether it should be electric welded, acetylene welded, or thermit welding.

I would like to ask the speaker whether this electric arc welding has its place only among the work that he described, or whether it is going to be applicable to all sorts of work.

A. J. Standing†: I like Mr. Bissell's paper very much. We all realize that pioneers in any field meet with a certain amount of opposition. Too much credit cannot be given to the Westinghouse, General Electric, Lincoln Electric, Morgan Engineering, and some of the others, for their pioneer work in the game of structural welding.

In the plant with which I am connected we are accustomed to use the metallic arc, carbon arc and thermit welding. Each one has a particular field, and the type of welding which we use for various jobs depends to a large extent on what our experience has taught us, and what happens to be the best particular method for that particular job. Now metallic arc work has a more general field than carbon arc work. Carbon arc work with us is used primarily for building up spindles, housings, and work of that nature. The metallic arc is used in our shop repairs for building up shafts and certain other work on our heavy castings such as side frames for charging machines, etc. We still rely to a large extent on thermit welding, gas welding is used, of

*Supt. Elec. Dept., Carpenter Steel Co., Reading, Pa.

†Elec. Supt., Saucon Plant, Bethlehem Steel Co., Bethlehem, Pa.

course, in general shop work—pipe connections, and work of that kind.

I was fortunate in having the privilege of reading Mr. Bissell's paper, I think, in the August issue of the American Welding Society's journal, and I also read a paper by Mr. H. P. Egan published in January in the same journal, in which he discussed a building erected in Canton, Ohio, for the Peerless Automobile people, a two-story garage and storage building. Now that building was put up by the Morgan Engineering Company, I believe, in connection with the Lincoln Welder Company.

But going back to Mr. Bissell's paper, there are a number of features of interest. The structural people naturally are skeptical. One of the points they bring up is that welded material depends so much on the personal equasion of the welder; they claim welding is not subject to inspection.

Another point that has been brought up, and fairly so, is that Mr. Bissell shows failure of the parent metal and not of the weld. It has been very commonly questioned whether or not the failure of the parent metal cannot be attributed to the effect of the weld.

Another feature of interest is the amount of weld necessary to balance a certain riveted section. In other words, how much weld do you suppose will balance a certain size riveted joint? I think a lot of these points will naturally have to be threshed out to get this down to a commercial basis.

Only two years ago two very competent engineers said, "We will never live to see the day that welding will replace rivets." That we know is the attitude taken to all steps in advance in any new industry. Whether this welding will be practical in heavier work as well as lighter work remains to be seen. In referring to heavier work, I want to call your attention to the effect of the change in building design to conform to the "zoning laws." In other words, the columns used in building on the zoning principle must be heavier than they are at present That precludes the possibility of using standard heavy rolled sections. For example, there is work going through our shops at Bethlehem where they use a section which runs in the neighborhood of 280 lbs. per foot, and I have seen as high as four inch cover plates riveted to that section to take care of base loads. The building will probably run up eight or ten stories then be zoned in, and go up 10 stories and so on. That presents a peculiar problem, and whether the strength ratio between the welded metal you can put on a column will be comparable to the strength of riveted joints must be very definitely determined.

These are two or three of the questions I would like to have more light on before we consider this thing settled. It is only two or three years ago that the first steps in structural welding were supposed to be along the lines of spot welding, the idea being that the spot weld would to a certain extent balance in quantity and strength a given amount of riveting. I think it has been pretty well decided that spot welding is not the answer, and that metallic arc welding, if it does cover the field, will be the form in which the work is finally done.

W. L. Warner*: I am very much interested in Mr. Bissell's paper. I have had the opportunity of reading it in the American Welding Society's paper, which one of the speakers has already mentioned, and I may say these tests that Mr. Bissell has described are very startling. They are startling not only from the standpoint of structural men and steel men, but also from the standpoint of the welding people. As Mr. Bissell has said, the tests he has been describing are made primarily, not only to convert the skeptical people to this idea of welding, but also in order to advance welding in the structural field.

We know, and it has been stated at various meetings of the Welding Society, that in order to enable the designer of steel building or structural steel of any kind to make an economical design he must know what the unit strength of the weld is.

We have made tests at Schenectady—two series of tests—with the idea of determining what those values are. I do not want to go into the details of those tests; but seeing the samples which Mr. Bissell has shown on the screen, I am sort of led to do some little figuring as to just what these tests which he has described, mean in the way of unit stresses. I do not know at the present time what the size of the weld bead was. For instance, in that sample he showed on the screen, I do not know whether he used the force of the machine required to press the eyebeam down between the two uprights to failure which occurred due to buckling of the cross member at a certain load of forty tons. I believe he did.

Now I have made a few approximate figures on that basis of forty tons. There being approximately nineteen lineal inches of weld around the joint at one end, it gives a load of about 2100 lbs. per lineal inch. That 2100 lbs. per lineal inch necessarily imposes a certain unit shearing stress and a certain unit tensile stress on the weld, and the amount of that stress will depend upon the size of the weld. Consider the triangular cross section with a leg of ¼" in length. Call that a ¼" bead. The ultimate stress imposed in that weld is about 24,000 lbs to the square inch. 24,000 lbs. to the square inch on a weld of that kind is about one-half of the breaking strength. If that is the case we would expect buckling of the members joined. Now if we consider a larger bead than that, the actual stress in that weld is much less. If we consider it a ⅛" bead, that ultimate breaking strength goes up to around 46,000 or 47,000 lbs. per square inch, and the shearing strength from the tests I have made is approximately 36,000 lbs. per square inch. The ultimate tensile strength runs anywhere from 45,000 to 60,000 lbs.; but for safety and design, I have been accustomed to using 40,000. Now these computations show that the welds were not stressed up to the ultimate value which they would stand. It is necessary in designing work to find out just exactly what stress the welds will stand in order to make economical designs. We are accustomed from the standpoint of psychology (I suppose for the sake of people outside who are not acquainted with the possibilities of welding, perhaps) to make the weld stronger than it needs to be in order to make it look stronger. I know we have tanks in our own plants that have more welding than they need to carry the stress imposed, because the fellows who do not know so much about welding think it looks stronger. That is the tendency that must be vercome for economical design. It is possible to design welding cheaper than you can rivet-

*General Electric Co., Schenectady, N. Y.

ing, but you cannot do it if you put too much weld in, and it is that feature of this business we must investigate in order to have it used in the structural game. The welder must be prevented by some means from putting too much welding in his joint and running up the costs. It can be done by proper design and supervision or something of that description to make the welder do this.

I might say the American Bureau of Welding has organized a committee to investigate this whole subject. Mr. J. H. Edwards, of the American Bridge Company, is chairman of that committee. Now they have not gone very far on their program, but they are going ahead, and as the plans are they are going to do a thorough job, and they need the assistance of you people. They need the assistance of the structural steel men, and not only the steel men, the men who build the steel jobs, etc., but the assistance of everybody concerned in the steel industry.

It is very difficult to roll certain structural shapes and yet we should get the most economical design, which will carry the stress properly from one part to another. It is possible to use T's instead of angles and obtain better stress distribution. Of course it is possible to use two angles, but two pieces being joined by welding runs up the cost. There is one possibility where the steel industry can assist in this development of welding and that is to roll these desired sections of larger sizes.

While we have done considerable structural welding, yet at the present time it is not in the state of being a commercial possibility.

Mr. Bissell mentioned one thing, and I want to disagree with him to some extent in regard to this, and that is about nitrogen in the weld. He said nitrogen caused brittleness. I don't want to contradict him or anything like that, but I want to say this: We have found by surrounding the welding arc with 90 per cent nitrogen and 10 per cent hydrogen, that the weld will show a tensile strength beyond the average of the ordinary metal arc weld. I have not seen any photo-micrographs to show whether or not there is any nitrogen in the weld, or whether the absence of nitrogen or the presence of nitrogen gives ductility.

If you come to Schenectady, we will be pleased to show you the results of our laboratory work.

Joseph W. Meadowcroft*: It is very gratifying indeed to have opportunity of being with you tonight. Being vitally interested in the advancement of the welding art in connection with the manufacture of All Steel Automobile Bodies, and being somewhat versed on the subject of welding, I would like to take sort of a defensive stand against Mr. Bissell and Mr. Warner, both associates of mine in the Society. I believe we may be able to bring out some points that may be of interest to you.

In the first place, we all know about the skeptical engineers. I might just for a minute touch upon a point with which you are all familiar, and that is the question of progress. This gentleman here, mentioned the fact that regardless of what advancement might be made in welding, there are certain obstacles to be met.

I recall at one time—if you will pardon me for getting off the subject—operating an electric spot welder at about sixty strokes a minute. In view of the competition, both in the welding field and in the line of work which we follow, it was necessary to speed up that particular equipment. The electrical engineers decided that if we were to watercool the contact points in switches to speed up operation, we would have a considerable number of accidents in the plant. At the time the electrical engineers made this statement, we had been running six months, and changed the speed from fifty to one hundred and fifty spots a minute and they are running today. This is an example of dangers of skepticism.

Captain Caldwell, of England, came here to show the American people how to arc weld ships together. These are naturally large structure. We were very much interested, as welding men, to have Captain Caldwell teach us more about the art. We talked a great deal about ships, but did not weld many, as Mr. Bissell and Mr. Warner might tell you. However, even though welded ships are still on the seas, and welded buildings are still standing, many people are skeptical.

I recall a meeting in Cleveland which I attended and took part in the discussion concerning the welding of large structures, and during the discussion, I mentioned the fact that while visiting the New York Shipbuilding Company, I asked Mr. Andrew, who was general manager, why they did not weld ships. He said, "Why should we weld ships? We have always made money riveting ships." I asked Mr. Andrews if he thought of the day coming when it would be necessary to meet competition, and he replied, "When it comes, we will meet it." In later years the New York Shipbuilding Company started to arc weld parts of the ships, which proves that due to the fact that there are so many skeptical engineers when it comes to welding problems, it is always necessary to start in a small way to convince the engineers, but you cannot criticize the engineers destructively because they are dubious about what can be accomplished.

Supervising, in the plant with which I am connected, over a thousand electric spot welding men; 422 acetylene gas welders, and 22 metallic arc welders, I find we have some failures. We train all of our men and have done so for years. We have been making coupons and they stand up in their tests on a piece work proposition but we will, no doubt, have some failures in welds on structural buildings as long as they are made by hand. However this does not mean buildings will fall down, but a small percentage of welds will require rewelding after inspection. This we cannot condemn as many rivets require repairs after inspection. The day is not far off, when we will have experts perform this welding work. They will weld coupons, the same as they do in the welding of pipes, before they are permitted to weld on the job, and we know that we will have good supervision. I cannot say perfect supervision, because not one of us is perfect, and we still have the human element to contend with.

My thought as a welding man in connection with this entire proposition, regardless of whether it be a building, a tower, a boat, a bus, or a trolley car, is that we must all work more along the lines of automation. We ask how that can be accomplished. It must be accomplished or we will never satisfy the architects and engineers. No man can determine whether another man is going to make a perfect job

*Supt., Edw. G. Budd Mfg. Co., Philadelphia, Pa.

of welding by hand, no matter what method he uses —electric spot, arc, or gas. How can perfection be accomplished? Automation! As an illustration—take the acetylene welding of the rear axle of an automobile which consists of 84" of welding. These were acetylene welded by hand at a cost of 80c, and there were failures of welds. They are now being arc welded automatically at a cost of 15c with no failure of weld. The penetration is controlled. 75% of the length of the weld is made by 75% penetration, and the other 25% is about 100% penetration. This difference in penetration is necessary, due to more strength in welds being required on the ends of axle housings. Regardless of this fact, you have that controlling element, that not only gives you the real strength in the weld but gives you an economical side, which we must all consider. In making structures, many of the parts will be assembled in the plants manufacturing this structural work, and will be carried to the field or point of assembly. We all realize that, when erecting buildings in small towns or cities, where ground is available, a tremendous amount of field work may be done, whereas, in large, congested cities, where traffic is heavy, and ground is scarce, the handling of beams, etc., must be done more or less by hand. Some of it may be done semi-automatically, but I am sure the General Electric and the Westinghouse Companies are working toward that end, and that is the end which will eventually bring about the success of the assembly of large structures. This would mean a saving of 11% of material and 25% of labor, but of course, these figures change as each one of the welding engineers figures it out, due to the fact that it is natural for some to take short cuts in their particular design.

There is another phase to be considered along the economical side. Mr. Bissell has told us it is necessary to bolt these structures together, removing the bolts and rivets while the welding is being done. The thing that must be considered is the elimination of bolting entirely. This, I firmly believe, will be worked out successfully, but we must get to that point by automation.

The gentlemen here said they had gone into the spot welding of various structures but were not very successful. I just want to bring out a few points to show you how, during a period of years, some things change. During the war, considerable money was sepnt in research work in the spot welding of large structures. Very little success was had because of the fact that in most cases very little projection welding was done. Projection welding was done fifteen or seventeen years ago and is now being used again extensively on light gauge sheet steel. It is true it is very difficult to spot weld large structures with portable machines. However, there are certain structures of a light nature which permit the use of projections and spot welding, which will be done successfully. Welds made with projections can be relied upon to a greater extent than any other method of welding where the human element is relied upon. Projection welding is used on lighter metals in manufacturing various commodities, such as stabilators for automobiles, where there are twelve projections made on the piece and welded at one time. The welding of the larger structures will probably be handicapped somewhat, but I feel there will come a time when a certain amount of that work will be done by spot welding and electric arc welding, but I do not feel any one here tonight should feel convinced that the welding of buildings as a whole has met with the success that it will meet with in the very near future, and it is all due to the skeptical engineers, who have a perfect right to take this attitude until such time as they are convinved that each weld is a weld, and will stand up under the stress placed upon it.

Many times, as Mr. Warner told you, we used a considerable amount of metal when it was felt extra metal was not necessary. Mr. Warner's thought is a very good one, but there are times, when, from an economical standpoint, it pays to add extra metal. For example—when a piece is cut shorter than it should be, for an open joint, it would be better to add filler material to this piece and use it, than lose the entire piece. This, of course, can be done when finish is to be applied. We say, "What method should be used when there is a certain amount of finish?" In the first place, the method of welding that should be used in the manufacture of any commodity should be governed by the cost and the quality of welds. In cases of finish, there are times when it is necessary to arc weld, rather than acetylene weld, due to warpage, buckling, and so on.

The method of spot welding, however, is the most economical of all on light metal structures. I have no particular interest in any one phase of the welding art, as we use them all, but I feel that the method of welding to be used should be decided more by the welding engineer than by the men who design the jobs. Now I do not necessarily mean that we should leave this responsibility entirely to the welding engineer, but I feel there should be close co-operation between the engineers.

As an illustration, take the automotive industry. You cannot imagine the waste in that particular industry, caused by some particular engineer wanting certain lines on a body. These certain lines may mean a change in the tools amounting to $1,000,000. However, through the simplification of the lines and the determination of the management to economize, a standardization in that particular field has been brought about. The automotive engineers today are working hand in hand with the purchasing division and the welding engineers. Why? For simplification and economy in the manufacture of automobile bodies.

Just as in the manufacture of automobile bodies, the feeling is gradually growing in the structural field, that there is more to welding than was at first thought, and that welding can be applied with the result of mass production at a lower cost. Of course, this also requires the co-operation of the electrical engineers, mechanical engineers, welding engineers, etc.

P. T. Vanderwaart*: The welding of structural steel members is attracting a lot of attention. From some of the statements made tonight, it appears to have economical advantages; a twenty per cent reduction in cost being possible. Undoubtedly in the near future it will come to play quite an important part in our daily life.

One of the most striking things at the present time to me is that the human element enters so largely into the making of a joint. The job must be

*Elec. Engr., New Jersey Zinc Co., Palmerton, Pa.

done apparently by expert men, in order to be sure that the joint is up to the strength which it should have. In other words, a poor workman could possibly weaken the structure below the value of a riveted joint.

The growth of this new art will probably be from two directions. On the one hand, the larger steel fabricating and erecting companies will develop expert welders just as several years ago they developed expert riveters. On the other hand, in industrial plants we now find electricians experimenting with electric welding and applying it to the solution of many problems in each particular plant. It is probably only a question of time until these two lines of activity grow to cover the entire field and the day of the rivet will be over.

I recently read an editorial in the Electrical World, I believe it was, mentioning the numerous applications of electric welding, and it seemed to this editor perfectly feasible that electric welding might even extend to cover the field of transmission and outdoor substation structures. That brings up a point that has not as yet been mentioned this evening, and that is, we will then face the old problem of painting versus galvanizing. I believe most engineers today believe in putting up their steel structures galvanized and getting away from the interruptions and dangers and cost of painting. I sincerely hope that the advantage of welding will not drive us back to the paint brush.

A. G. Bissell*: From our experience in welding of galvanized material, we would weld it on and before the weld started to get cold, we would brush it good and hard and add our weld galvanized at the end of the process, and while it was thinner than the original galvanized, a peculiar thing was that the welded metal would take it.

The tinners also told me that welded metal would tin much better. Take substation fixtures and transmission towers. I think if you take that material galvanized and weld it by distributing very little galvanizing around the weld, give it a coat of aluminum paint, it seems to stand up pretty well in the winter.

John C. Reed†: My experience in welding is foreign to what has been mentioned here tonight, but we are doing something at Steelton, which so far as I know, is not being duplicated elsewhere. We are re-welding the treads and flanges on crane track wheels. These wheels with their axles are placed in a lathe to which we have attached an automatic welding machine and the treads of the wheels are rebuilt in this manner. The flanges of the wheels are built up by hand welding. This could also be done with an automatic machine with the wheel revolving in a manner similar to that of the table of a boring mill. We are using high carbon welding wire for this work the carbon content being from 1.00 to 1.10. After the welding process the treads and flanges are ground to size. Before starting the welding process, these wheels are boiled in a soda solution to remove all traces of grease which may have worked into the pores of the steel. These wheels, we find, last longer than the original wheels, due to the fact that we have a harder surface on the treads and flanges.

H. A. Hornor*: To dispel doubt as to the safe use of the process of manual arc welding there are three essential things to be taken care of, namely, a consideration of the materials to be welded, and their use after welding, the design of joint, and the proper precautions of testing the weld. This latter should be done while the work is in progress. As to the first two points, i. e., the materials and their ultimate use and the design of the joint, it is found frequently in practice that the problems are attempted by those who are not conversant with the practice or theory underlying the electric welding process. This condition it seems can only be improved by an educational propaganda such as the excellent paper presented by Mr. Bissell.

It is sometimes said, and more often thought, that there is no method or methods by which a good electric weld, or a poor one, can be discovered after it is made. This is not true. There are at least three simple and practical methods of determining the soundness of electrically welded joints. The first consists of the familiarity of the tester with the contour and external appearance of the weld. The second is by means of the use of kerosene which is important in tank construction, particularly such structures as are used to contain either light oils or gases under pressure. The third method of testing requires a partial destruction of the weld and is by means of chipping out the material. To be sure, this does mean a partial destruction but it will confirm the uniformity of the work and is an important check-back, not on, but for the benefit of the electric welding operator. As a matter of fact, the trustworthy electric welder should desire to have portions of his work chipped out from time to time so that he may be able to correct, either by the electrical sources of power behind him or his own manipulation, those avoidable or unavoidable interferences which are well-known to appear in the practice of electric arc welding. In addition to the aforementioned practical methods of testing there are a number of what may be called, for the sake of a better name, impractical methods. These have not been commercially developed and in many cases have not been deemed of sufficient necessity for the expenditure of money essential for the proper apparatus. As in any serious jointure of materials so with electric arc welding, if engineers wish to use the process without danger to human life the proper precautions for the insurance of perfect work must be done.

R. M. Fuller†: The question I wanted to ask has been mostly answered. I would like to ask Mr. Bissell the difference in the estimated cost between a riveted building in the field and shop and a welded building. Also, how they are going to make a clean welding job when the time comes to remodel the structure he has showed us on the screen.

A. G. Bissell: Simply take off with a torch. Use your gas torch and cut it against the beam.

The cost of this one building we put up at East Pittsburgh represented a 20% saving of steel and erection. In reality we did not make that, because our steel gang was not familiar with outside erection.

*Gen. Engr., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

†Elec. Enginerr, Bethlehem Steel Co., Steelton, Pa.

*An expert on Electric Welding and formerly with the New York Shipbuilding Company.

†U. G. I. Contracting Co., Philadelphia, Pa.

Our estimate for that building for riveting erection was about $5,000. We put the building up for $4,200. On the second building the cost for riveting would have been $3,900. We welded that for $2,872, making a saving of a little better than $1,000. The use of welding is very well adapted to this changing of a building. We had to remodel a number of our buildings with columns backed up with brick. We simply cut the brick, laid an eyebeam against that column and welded it in place. Where the columns were not heavy enough we took a channel and set it over a column and welded it—reinforced columns—the same as has been done in Detroit some time ago. This shows some things that have not been brought out. They put an addition on a department store in Detroit. Each joint of the old member was brought in against the existing member and arc welded. In 1919 the Navy Yards helped us out in a great many difficult propositions. The riveted steel cost around $8,000 to install a ship in drydock, and it took about a month. The next ship that came in we welded at a cost of $3,900 and the ship was in dock just nine working days.

A. J. Standing*: I want to take some information from this meeting. There is one question in my mind as to building. In the first place the architect designs it. Then the concern takes it over to build that building. The next step is to detail the drawings. Then it goes to the fabricating shop, and there it come in touch with two very important men—the layer-out and the pick-up men. If you put that building together electrically welded, each individual piece must be laid out before it can be erected. You cannot take your material up in the air and get your welder to put it in the proper place.

A. G. Bissell: What I did say was to have a fitter and his gang there. Three or four men lay out the steel and get it ready for the welder. Some of our stringers were made up of two channels, toe to toe. The fitter got that ready and clamped it. The welders went ahead. The same with the crane girders. When the fitters got a piece ready they clamped it and marked it for the welder. In the erection of this building we put in a flanging angle, three tiers, I think. The middle tier was punched, and we burned a bolt hole in the stringer to fit it in. We bolted this entire set of stringers and then stuck in our wind bracings, pulled our columns plumb and straight, then set on our trusses and clamped the member columns down The welder took the clamps off and threw them to the next job. We went along quite rapidly in putting the building up. In the Sharon building I understand each member will be bolted by two bolts. In that way they will bolt up an entire day before they start to weld. Does that answer your question?

A. J. Standing: Yes.

A. G. Bissell: You will have to have a fitting gang the same as you do for riveting, but you will have one welder. A rivet gang has probably three or four men, but one of those men will be replaced by a welder on an individual joint. It took the welder a little less than an hour to attach that 15-inch bracket to the column. That meant on that job about 85c to 90c labor. It took about 2½ or 3 pounds of welding to put on that bracket. There is about 25c. And the power to put that on, 25c. A little less than $1.50 to attach that bracket. If I am not mistaken it will take about 20 rivets to put on that same bracket. I wonder if some one who is experienced enough will tell me if that can be done for less than $1.50 by riveting?

F. O. Schnure: On your structural steel welding do you use bare or structural wire?

A. G. Bissell: We use bare wire. On the field work the men are using corded wire because it maintains the arc better. My experience on shop work or yard work is that the bare wire is preferable.

F. O. Schnure: Are those the only benefits that accrue from corded wire?

A. G. Bissell: The manufacturers of corded wire, claim it gives better speed. Perhaps it does, but you sacrifice penetration and some of the other advantages. I would rather go a little slower and get better penetration.

Question: In looking over some of the literature on the subject, I have seen a good many cuts where the members have been beveled in, so that you had a V shaped section to be filled in with your arc metal. Is that supposed to be necessary in certain construction?

A. G. Bissell: If you are going to join two very heavy sections, where you have an excessive amount of material on the sides, perhaps you ought to bevel it, but in the average building construction I do not think there are very many joints you would want to bevel The area of welding metal surrounding the old metal should be one and one-half times the area of your cross section surrounding your joint.

*Supt. Elec. Dept., Saucon Plant, Bethlehem Steel Co., Bethlehem, Pa.

THE JUNE ISSUE OF

Iron and Steel Engineer

Will Completely Cover the

Twenty-Third Annual Convention and Iron and Steel Exposition

Among the major points to be covered in this issue are: Editorials by the leading engineers of the Iron and Steel Industry; advance copies of all papers to be presented at the technical sessions of the convention; complete program of events of the week; lists of exhibitors (alphabetical and numerical); national committees; local committees and exposition committees; a complete story of one of the major events of the week—an inspection trip to one of the large steel companies in the Pittsburgh District and other items which will be of interest to those in attendance.

Items of Interest

The R. D. Nuttall Company have just developed and placed on the market a series of reduction gear units for heavy service. There are six units in the series and they completely cover a range of from 150 to 2,000 horse power. They are designed for services that require transmitting heavy loads at relatively high speeds, such as main and auxiliary drives in steel mills, the driving of crushers, hoists, pumps and other similar heavy equipment.

The Units are equipped with either Nuttall 7½° single helical or Nuttall Herringbone gears, treated or untreated depending on application. They are furnished as desired with either sleeve or Timken Tapered Roller Bearings. It is possible to replace one type of bearings with the other because the bearing housings are identical in both types. However, in case of a change new shafts would have to be provided.

The gears are totally enclosed in a cast iron case fabricated to lessen the weight. Thus, they are carefully protected from grit and dirt. The bottom of the case serves as a reservoir for lubricant and the gears run in a bath of oil while the bearings are lubricated by a positive splash system. The same lubricant is used for both gears and bearings.

The Crouse Hinds Company, Syracuse, New York, introduces the:

Type LCE Imperial floodlight projector which is a new and more efficient unit for floodlighting railroad yards, large buildings, and other large areas. The greater efficiency is obtained by the design of the reflector which is 24 inches in diameter and parabolic in shape. This reflector intercepts and redirects into the beam a greater proportion of the lamp rays than has heretofore been obtained.

The case is of cast aluminum alloy, which resists all corrosive gases. It is practically air tight, the large radiating surface making the usual ventilators unnecessary. This feature prevents dust and dirt from getting into the case and collecting on the reflector. The door and case are ground to fit so that no gasket is necessary.

Two simple resetting devices are provided by means of which the projector case can be released from its position, tipped completely over, or turned around for cleaning and relamping and then returned to its exact original position.

When used for railroad yard lighting, type LCE Floodlight projector can be supplied with a 15-inch hood, which throws the stray light immediately beneath the tower, and also prevents soot from falling on the lens.

A connection box on the back of the floodlight with binding posts makes wiring very easy. The lamp focusing mechanism is very simple to operate as it is all controlled by means of one wing nut on the outside of the case. The door is provided with spring clamps which are the quickest device for adjusting, as all that is necessary is to slip the catch in place and the springs hold the door at the proper tension.

The lamp generally used in the type LCE floodlight projector is the standard 1000-watt PS-52 lamp. When a narrower beam of light is desired, the receptacle and focusing mechanism can be placed in the bottom of the case and arranged for 500-watt or 1000-watt lamps in G-40 bulb.

The Bussmann Manufacturing Company of St. Louis have just announced the purchase of a new four-story building located at University and Jefferson avenues. Mr. A. B. Bussmann, President of the firm states that this new building will more than double their present floor space. The entire Twenty-third Street factory and office has been moved into the new location.

The Bussmann Company has been one of the surprising youngsters of the electrical industry.

Announcement is made of the appointment of Mr. William Miller as General Manager of the Calebaugh Self Lubricating Carbon Company with headquarters in Philadelphia, Pa.

Mr. Miller was formerly Chief Engineer for the Calebaugh Company and recently had offices in Pittsburgh.

Mr. J. H. Albrecht has been appointed District Representative for the Pittsburgh district with offices in the Empire Building.

Announcement is also made of the opening of headquarters in the Chicago district. Mr. John M. Kelly has been appointed District Representative with offices at 6646 Stoney Island avenue.

The Shepard Electric Crane and Hoist Company, Montour Falls, N. Y., desiring a closer co-ordination of its motor supply with its electric crane and hoist business, has appointed Mr. Fred G. Bell to direct this new development. Mr. Bell was formerly president and general manager of the Zobell Electric Motor Corporation, Garwood, N. J.

International Combustion Engineering Corporation announces its removal with its American subsidiaries, Combustion Engineering Corporation, Ladd Water Tube Boiler Company, Raymond Bros. Impact Pulverizer Company, Inc., to the International Combustion Building, Madison avenue corners 35th to 36th streets, New York.

Edward F. J. Lindberg who for the past few years has been Manager of the Engineering Division of the Central States General Electric Supply Company is now associated with the Chicago Office of the Crocker Wheeler Electric Manufacturing Company as Sales Engineer.

Mr. F. D. Paulin, formerly connected with the Ludwig Hommel Company and the Square D Company joined the sales force of the Union Electric Co. under date of January 15. The Union Electric Company recently purchased a six-story reinforced concrete building 220x45 ft., located at Evans alley and Duquesne way and are now having it remodeled for their use. They expect to occupy the new building about April 15 at which time the trade will be notified of the change in location.

The Rockbestos Products Corporation of New Haven, Conn., manufacturers of asbestos covered wires and cables, announces the opening of their own sales offices in the Union Trust Building at Pittsburgh, Pa.

J. S. Rashba, formerly with the Test Department of the New York, New Haven & Hartford Railroad, and until recently sales engineer with the Rockbestos Products Corporation, will be in charge of this office.

Ford W. Allen, formerly with the Garfield Manufacturing Company has been made assistant to Mr. O. D Allen, manager of the Chicago office of the Rockbestos Products Corporation.

Mr. Leahy, Power Engineer of National Tube Company plants at Pittsburgh, has accepted a position with the Youngstown Sheet & Tube Company, and he will have charge of the Fuel Division of this Company.

F. E. LEAHY

Mr. Leahy is an active member of the Association of Iron and Steel Electrical Engineers and has taken an active part in the affairs of the Society for the past ten years.

His host of friends wish him success in his new position.

The General Electric Company announces another addition to its line of welding equipment, a small engine driven welding outfit. This set incorporates the G. E. WD-11 welding generator with a continuous rating of 150 amperes and a one-hour rating at 200 amperes, the current duty range running from 50 to 250 amperes.

The generator is driven by a Continental P-20, Power Unit rated 18.22 horsepower S.A.E. and capable of developing 23.5 horsepower at 1,400 r.p.m. The generator is equipped with a control panel, rheostat and self-adjusting stabilizing reactor. The engine accessories include a strongly constructed radiator, pressure feed lubricating system with oil pressure gauge and indicator, vertical tube gravity feed carburetor, air cleaner, centrifugal governor, starting crank, 10-gallon gasoline tank, tool box and sheet metal hood with sheet metal side panels which can be locked in place.

The outfit is particularly adaptable for oil field work, shop and garage work where portability is desirable or for any application where no power supply is available for driving a motor generator type of welder.

Among the advantages of this combination are low first cost, light weight and reliability. Tests have shown the outfit capable of standing up under hard service and overloads. The set is mounted complete on a structural steel base so designed as to facilitate easy moving from place to place.

—"SO AND SO HAS STANDARDIZED ON"—

(Continued from page III)

aforesaid piece of equipment decides to take a rest, and your inspector finds that one of the "whirlygigs" is beyond further duty so you attempt to order a replacement. After a period of time, instead of the replacement you get a letter saying that "whirlygig" No. 12345-B has been superseded by "whirlygig" No. 54321-B, and requires three extra pieces of ginger-bread, and a blue print before it can be installed on the "obsolete" equipment, and an extra charge of $1.13 should be authorized to cover the idea. And you realize that a "standard" does not include any conception of time in its life—and also find out before the new pieces arrive that the mill electrician, with a piece of wire and a few "whirlygigs" of his own, has the equipment back in service.

Or it may be that the equipment stood up in service 100%, and you admit you have found something better and decide to buy a few more. The order is placed for duplicate equipment, and you afterwards learn that the designer had an idea in the meanwhile that the apparatus should be long and thin instead of short and fat, and that style No. 123454321 will be furnished on your order—so the storeroom man gets another bin ready in his museum of spare parts.

A recent article on this subject drew a comparison between the "Little Red School House" and modern palaces of learning in an argument for a change from the "old to the possibilities," and as the "Little Red School House" was the "Alma Mater" for many of us, and naturally stands well in our memories, so it is with a lot of the old equipment. A lot of these old veterans were manufactured at a time when a horse power and a horse had some definite relation, and the designers took no chances on the nameplate not being correct—and these old boys and girls go on year after year pulling double load without laying down on the job, and their maintenance requests are not great. So, perhaps we are a little reluctant to throw out an old friend for something that may be "just as good."

So it is a tough job sorting out the "bunk." We want to keep up with the modern designs—but the designers work faster than we can approve their efforts—we want to improve equipment, but like to be certain we will get an improvement; are accused of being backward when we are just cautious, and in the meanwhile the notice still reads, "Bring the Inventory Down."

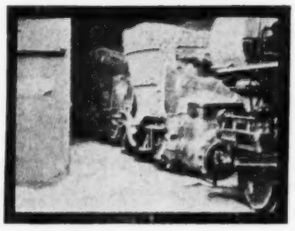
THE EXPOSITION
OF ENGINEERING DEVELOPMENTS

FOR THE

Iron and Steel Industry

AUSPICES

Association of Iron and Steel Electrical Engineers



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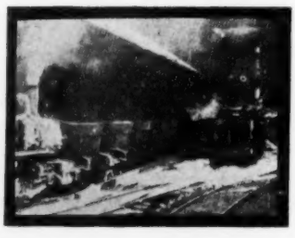

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